GEO-SPATIAL ASSESSMENT OF CHOLERA AND IDENTIFICATION OF PATHOGENIC BACTERIA FOUND IN SELECTED WATER SOURCES IN ILE-IFE, OSUN STATE, NIGERIA

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ABSTRACT

This study mapped out the environmental risk factors associated with cholera in Ile-Ife and investigated the spatial relationship between cholera incidences and environmental risk factors for it. It also determined the presence of *Vibrio cholerae* and other pathogenic bacteria in selected water bodies in the study area. This was with a view to providing information on the predisposing and enhancing factors associated with cholera in the study area.

Recent high resolution image of the study area and a land-use/land-cover map were used to identify environmental factors associated with cholera in the study area. A Global Positioning System (GPS) unit was used to identify other point and non-point sources of environmental risks including the location of refuse dumps, abattoirs, markets, rivers and wells. Streams and river network at the LGAs were digitized. The GPS datasets were plotted on a high resolution satellite imagery of the study area and the land-use map of the study area for cross examination and visualization. The environmental factors were ranked accordingly, weights were assigned to them and a suitability analysis was carried out using ARCGIS software. Spatial analysis was carried out to stratify the study area into eight cholera risk zones. Water samples were taken from rivers and wells in each of the zones and then tested for the presence of *Vibrio cholerae*and other pathogenic bacteria. The result of the *Vibrio cholerae* and other pathogenic bacteria count per sample were used to build up the attribute for each of the water sample points on geographic information system map. The level of contamination was then displayed on the map and integrated with the cholera database to produce an environmental risk map for the study area.

Waste dump sites, abattoirs and markets were mapped out as the environmental risk factors (ERFs) associated with cholera in the study area. It was observed that there was an association between the ERFs ($p < 0.001$). Similarly, 18 out of the 44 waste dump sites located in the study were near the historical cholera cases. Also, seven out of the 18 markets in the study were observed to be near the historical cholera incidences. Finally, two abattoirs were selected out of 36 abattoirs to be proximal to the historical cholera cases. Furthermore, *Vibrio cholerae*(7.3%), *Klebsiellapneumoniae*(12.7%, 3.6%), *Enterobacteraerogenes*(9.1%, 3.6%),*Citrobacterkoseri*(0%, 7.3%), *Escherichia coli* (3.6%, 7.3%),*Klebsiellaaerogenes*(7.3%, 5.5%),*Citrobacterfreundii*(7.3%, 1.8%), *Salmonella typhi*(7.3%, 3.6%), *Pseudomonas aeruginosa*(5.5%, 1.8%),*Shigelladysenteriae*(5.5%, 3.6%)and *Proteus mirabilis* (3.6%, 0%) were identified from wells and streams in water samples respectively. The environmental risk map produced for the study showed the ranges for the colony forming unit (CFU) counts with the population at risk.

The study concluded that waste dump sites and market had the highest predisposing attribute to cholera.

Keywords : environmental risk, cholera incidences , *Vibrio cholera*.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Cholera is an acute intestinal infection caused by the ingestion of food or water contaminated with the bacterium *Vibrio cholerae* (WHO, 2002). Cholera has a short incubation period, from a few hours to 5 days, but commonly 1-2 days. *V. cholerae* produces an enterotoxin that causes copious, painless, watery diarrhea that can quickly lead to severe dehydration and death if treatment is not promptly given. Vomiting also occurs in most patients (Sack *et al*., 2006). Cholera affects all ages and both gender (Sack *et al*., 2006)

Cholera can be categorized as an epidemic or endemic disease. The epidemicity and endemicity of a disease depend on the characteristics of the pathogen, and those of the environment. Epidemics of cholera are characteristically sudden and often create an acute public health problem. They have a high potential to spread fast and cause death (Park, 2009)

Cholera as a disease is endemic in Africa, parts of Asia, the Middle East, and South and Central America (Adagbade *et al.,* 2010). In endemic areas, outbreaks usually occur when war or civil unrest disrupts public sanitation services. Natural disasters such as earthquake, tsunami, volcanic eruptions, landslides and floods also influence outbreak by disrupting the normal balance of nature (Qadri, 2005). Such creates many health problems, food and water supplies can become contaminated by parasites and bacteria when essential systems like those for water and sewage get compromised. Developing countries are disproportionately affected because of their lack of resources, infrastructure and disaster preparedness systems (Sur, 2000). Human behaviors related to environmental hygiene, personal hygiene and food preparation contribute

greatly to the occurrence and severity of cholera (Ryan and Ray, 2004). Transmission is usually due to fecal contamination of food and water as a result of poor hygiene. The bacterium can live naturally in any environment especially in brackish rivers and coastal waters (CDC, 1987).

In Nigeria, the cholera is endemic and outbreaks are not unusual. In the last quarter of 2009, it was speculated that more than 260 people died of cholera in four Northern states of the country with over 96 people in Maiduguri, Biu, Gwoza, Dikwa and Jere council areas of Bauchi State (Igomu, 2011). Again in Nigeria, the first series of cholera outbreaks were reported between 1970-1990 (Lawoyin *et al*., 1999). Despite this long experience with cholera, an understanding of the epidemiology of the disease, aiding its persistence in outbreak situations, is still lacking (Gyoh, 2011).

Geographical Information System

A Geographical Information System (GIS) can be defined as a computer system with the capacity to capture, store, analyze, and display geographically-referenced information. In other words, it is an informatics for storing and managing data that has been identified according to location. GIS comprises an organized collection of computer hardware, software, geographic data and personnel, designed to effectively capture, store, update, retrieve, analyze and display all forms of geographically referenced information. (Ashok, 2015)

Geo-spatial information technology has numerous applications in human health. At the very basic level, the complete research and practice domains within health care and management are strongly grounded in the spatial dimension (Meade *et al.,* 2000). The ground breaking contributions of Dr. John Snow, in highlighting the cholera epidemic of London in 1854, not only launched the field of epidemiology, but did so in a manner closely linked with the visual display of spatial information (Tufte and Moeller, 1997).

Geo-spatial Information Technologies, an umbrella term covering a wide gamut of GIS and related technologies (Remote Sensing, Geographic Information System, Global Positioning System, Image Processing, and Location Based services), is widely believed to play an increasingly important role in the present day research (Sihag and Satpal, 2015). Health problems have special association to local geography; especially vector borne diseases can be effectively analyzed using mapping and modeling techniques (Longley, 2000)

Satellite images can greatly enhance mapping of the environmental factors associated with cholera risk just like some other infectious diseases. Integrating satellite images, spatial statistics and GIS can provide public health officials with vital information needed to predict and manage cholera outbreaks. GIS has also been used extensively in epidemiology for disease surveillance and intervention monitoring (Clarke *et al*., 1996). By mapping disease cases in a geographic space, local and national governments can easily identify the distribution and spread of disease across geographic regions, optimize planning of intervention locations, and monitor their effectiveness.

The prime goal of environmental and health management is to reduce existing risks and prevent the introduction of new uncontrolled risks. Since alterations to human health are often associated with or caused by sudden or gradual changes in the environment, a prerequisite for health risk management is the identification of environmental hazards and their effects, coupled with suitable monitoring programs to provide the data necessary for priority setting and decision making (Longley *et al.,* 2010). The best technologies and their potential for application to monitor and manage the environment is with utilization of the power of functionalities available within the fast emerging Geospatial Technologies (GT), which will surely enable a

better management of environment and, in turn, better health management (Wang *et al.,* 2008).

1.2 Statement of the Research Problem

Cholera is one of the three diseases requiring notification to the WHO under the International Health Regulations (WHO, 1969). The others are Plague and Yellow Fever. It is usually transmitted through fecal contaminated water or food and occurs sporadically in any part of the world where water supply, sanitation, food safety, and hygiene are inadequate. A large amount of man's ill-health can be traced to adverse environmental factors such as water, soil, air pollutions, poor housing conditions, presence of animal reservoirs and vectors of diseases which create a constant threat to man's health (David, 2003; Frank and David, 2002)

More recently in Nigeria, and other developing nations, pollution of water resources has become a serious problem. Recently, the re-emergence of cholera has been noted in parallel with the ever-increasing size of vulnerable populations living in unsanitary conditions. The number of cholera cases reported to the WHO continues to rise. From 2004-2008, cases increased by 24% compared within the period from 2000 to 2004. For 2008 alone, a total of 190,130 cases were notified from 56 countries, which involved 5143 deaths. Many more cases were unaccounted for due to limitations in surveillance systems and fear of trade and travel sanctions. The true burden of the disease is estimated to be 3-5 million cases and 100,000-120,000 deaths annually (Ali *et al.,* 2012)

Vital to this is the outbreak which has led to 40,000 cases in Nigeria and resulted in 1,555 deaths, making a likely peak in a three-year-old surge of the disease in the country because the number of cases is three times higher than 2007 and seven times higher than in 2008 (WHO, 2009).

Beyond this is the recent outbreak of cholera that was reported by the African Cholera Surveillance Network (2016) that cholera affected Ajeromi, Apapa, Lagos Island, Oshodi, Isolo and Surulere local government areas of Lagos where 3 persons were confirmed dead out of 13 cases reported, while few others were said to have been discharged after treatment in Lagos and this outbreak came three days after 8 persons were confirmed dead at Plateau State. Also, ten communities in Andoni Local Government Area of Rivers State also suffered from an outbreak of this disease where at least 20 persons died. Also the dreadful outbreak in some areas in Ife East and Ife Central, especially at some places in Ife Central Local Government of Osun state, where no fewer than 2 people died and about 70 others were hospitalized in the Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife (Adagbada *et al.,* 2012) is to be noted.

Despite the fact that millions of people are already infected with cholera, and many have died of the disease, an increasing number of people are still contracting the causative organism without having adequate knowledge on the environmental risk factors associated with the disease. There is therefore the need to assess environmental factors associated with cholera risk in the Ile-Ife locality in order to reduce the burden and risk in affected communities, thereby preventing future outbreak of diseases, hence this study.

1.3 Aim and Objectives

1.3.1 Aim

The aim of this research is to determine the spatial relationship between the environmental risk factors associated with cholera in the study area.

1.3.2 Specific Objectives

The specific objectives of the study are to:

a. map out the environmental risk factors associated with cholera in the study area;
b. investigate and map out the spatial relationship between cholera incidence and environmental determinants of cholera;
c. determine the presence of *Vibrio cholerae* and other pathogenic bacteria in selected water sources in the study area; and
d. produce an environmental risk map for the study area

1.3 Justifications of Study

Cholera is a preventable disease that has to do with hygienic practices and how people relate to their environment. If people subscribe to proper personal and environmental hygiene, they will very likely be able to prevent cholera.

Some areas in Ile-Ife seem to have become foci for cholera outbreak due to poor environmental hygiene, which strongly imply that cholera outbreak could re-occur in such areas. Therefore, it is pertinent that these cor s be studied.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of Water to Life

The importance of water for sustenance of life cannot be overemphasized. Groundwater is a natural resource that is of immense importance to life. Groundwater constitutes over 90% of the world's readily available freshwater resources with the remaining 10% being in lakes, reservoirs, rivers and wetlands (Asonye *et al.,* 2007).

Water is one of the most important substances on earth. All plants and animal must have water to survive. If there was no water, there would be no life on earth; this is according to the Australian Government Department of Health. Water resources are used in various ways including direct consumption, agricultural irrigation, fisheries, hydropower, industries production, recreation, navigation, environmental protection, the disposal and treatment of sewage and industrial effluents (Medalye *et al.,* 2008).

2.2 Water Pollution in Nigeria

Pollution is the introduction of a contaminant into the environment. Olaniran (1995) defined water pollution as the presence of excessive amounts of a hazard (pollutants) in water in such a way that it is no longer suitable for drinking, bathing, cooking or for other uses. Pollution is created by industrial and commercial wastes, agricultural practices, everyday human activities and most notably, models of transportation. Also, the by-product of agricultural activities, urbanization, and industrialization results in pollution and degradation of the available water resources (Ajayi and Osibanjo*,* 1981).

Water pollution could occur when pollutants or contaminants are directly or indirectly discharged into water bodies without adequate treatment to remove the harmful compounds. Water is typically referred to as being polluted when it is impaired by anthropogenic contaminants and does not support human use, such as drinking. Natural phenomena such as volcanoes, algae blooms, storms, and earthquakes also cause major changes in water quality and in the ecological status of water. Water pollution can either be of point source or non-point source. Point sources of pollution occur when pollutants are discharged directly into the water body; for example, from industrial sewage or municipal waste water pipes. A non-point source delivers pollutants indirectly through environmental changes such as pollution from

urban run-off (Omole and Longe, 2005). Water pollution is the leading cause of water borne diseases worldwide and it accounts for the deaths of more than 14,000 people daily (Sa'eed and Mahmoud, 2014*).*

Surface and groundwater pollution is a major problem beclouding Nigeria and other developing nations (WHO, 2008). In Nigeria, available reports cite gross contamination of most water bodies across the nation by the discharge of industrial effluents, sewage and agricultural wastes among others (World Bank, 1998). Agricultural run-off is a major water pollutant as it contains nitrogen compounds and phosphorus from fertilizers, pesticides, salts, poultry wastes and washes from abattoirs. The World Health Organization in 2008 stated that of those affected by water scarcity, sanitation and pollution issues in the world, majority live in developing countries. The drastic increase in the Nigerian population that has resulted in the massive practice of indiscriminate dumping of wastes of all kinds in our towns and villages, increased use of fertilizers and other agro chemicals had also made water pollution to be accelerated. Today only 58% of Nigerians have access to safe water (WHO and UNICEF, 2005). Thus, most households have to resort to drinking water from wells and streams especially in the rural and suburban communities. These water sources are largely untreated and might harbor water and vector-borne diseases such as cholera, typhoid fever, diarrhea, hepatitis and guinea worm (Adekunle *et al.,* 2004; Fenwick, 2006).

2.3 Community Based Sources of Water Pollution

Water sources have been identified to be polluted by different activities associated with environmental risk factors such as: abattoirs, waste dump sites, markets, and restaurants amid others **(**WHO, 2012). Water contamination, as a result of environmental risk factors, can

lead to illnesses and death (UNICEF and WHO, 2012). Therefore, the environmental risk factors are explained below to describe the detrimental effects caused by these risk factors.

2.3.1 Abattoir

Abattoir has been defined as premises approved and registered by the controlling authority for hygienic slaughtering and inspection of animals, processing and effective preservation and storage of meat products for human consumption (Alonge, 1991). Abattoir Acts (1988) defined abattoir as any premises used for or in connection with the slaughtering of animals which meat is intended for human consumption and include a slaughter house but does not include a place situated on a farm. Animals slaughtered in abattoirs include; cattle, sheep, goats, pigs, and other equine animals.

According to the World Bank (1998), the total amount of waste produced per animal slaughtered is approximately 35% its body weight. Waste generated by abattoirs include solid waste, made up of paunch content, bones, horns and fecal components, slurry of suspended solids, fat, blood and soluble materials (Sangodoyin and Agbawe, 1992). These wastes from abattoir operations can be separated into solid, liquid and fat, which are highly organic. The solid waste includes condensed meat, undigested food bones, horns, hairs and aborted fetuses. The liquid waste is usually composed of dissolved solids which include; blood, gut contents, urine and water, while fat waste consists of fat or oil and grease (Bull *et al.,* 1982; Coker *et al.,* 2001; Nafarnda *et al.,* 2006). The major characteristics of the nature and composition of abattoir waste water are high organic content, sufficient organic biological nutrients, adequate alkalinity, relatively high temperature (20-30^{o}C) and free toxic material (Masse and Masse, 2002).

Abattoir wastes are hazardous waste and can affect water, land or air qualities if proper practices of management are not followed. It can cause pollution of soil with dung and the atmosphere with methane (a greenhouse gas) from decomposing wastes. Animal waste can be valuable for crops but can present trace heavy metals, salts, bacteria, viruses, and other micro-organisms sediment. Also, in certain types of soil; the waste can seep through the ground and reach groundwater, polluting it with nitrate and bacteria (UNEP, 1990). Meat processing industries (abattoirs) are generally less developed in developing countries like Nigeria unlike developed countries where waste generation, analysis and treatment are considered before constructing the abattoir (Ogbonnaya, 2008). The pollution load on a water body from abattoir effluent can be quite high, and can show a very high contamination which is hazardous to human beings and aquatic life (Mittal, 2004). Wells in vicinity of abattoirs which serve as source of water to the abattoir users were traced by Sangodoyin and Agbawe (1992) to be polluted by effluent from the abattoir and constitute health risk for the butchers and users of the wells. In addition, improper disposal systems of these wastes could lead to the transmission of pathogens to humans and cause zoonotic disease such as *Coli bacillosis*, salmonellosis, brucellosis and helminthiasis (Cadmus *et al.,* 1999). Coker *et al.,* (2001) identified seven pathogenic species of bacteria in abattoir effluent in the south western part of Nigeria. Oyedemi (2000) reported an association of some diseases with abattoir activities which include pneumonia, diarrhea, typhoid fever, asthma, wool sorter diseases, respiratory and chest disease. These diseases can spread from the abattoir to the neighborhood via vectors or animals (Oyedemi, 2000).

Fadare and Afon (2010) studied the waste handling practices from twenty-five (25) abattoirs in Ile-Ife. They established that 80% of the abattoirs were located along river banks where they could get adequate access to water supply. Blood, carcass trimming and snout

were identified as waste generated. It was discovered that the storage and disposal practices of these waste were not environmental-friendly as they are sources of land, air and water pollution. It was also observed that every abattoir had a well but the quality of the water was not a major consideration for them. They also discovered that the combination of water availability and accessibility to road explained why 80% of the abattoirs had their locations on urban wet lands and along the roads in the study area. Nearness to market was also discovered to be a determinant to the construction of abattoirs. The study concluded that, since waste from abattoir is special, efforts should be put in place to making sure that waste is not allowed to enter into the municipal solid waste management.

Eze and Ikeri (2010) reported observation of *Staphylococcus aureus, Cytophaga species, Bacillus spp, Micrococcus spp, Klebsiella spp, Vibrio cholerae, Aspergillus spp, Cladosporium spp* and *Rhizopus spp* from waste water samples which were contaminated with abattoir wastes in their study in Port-Harcourt, River State, Nigeria.

2.3.2 Waste Dump Sites

Wastes are materials that are not prime products (that is products produced for the market) for which the initial user has no further use of it in terms of his or her own purposes of production, transformation or consumption, and of which he or she wants to dispose at that time but may be a raw material to another user (Ray, 2008). Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities, but residuals recycled or reused at the place of generation are excluded (UNSD, 1997).

Waste dump site is a location for the disposal of waste materials where refuses are dropped. Waste is one of the most important resources of contamination of soils and water

because they are deposited on soil, inside rivers and streams serving as dump sites for humans. There are many waste types defined by modern systems of waste management, notably:

a. Municipal waste: this includes household waste, commercial waste, and demolition waste.
b. Hazardous wastes which include industrial waste and biomedical waste (clinical waste).
c. Special hazardous waste which includes radioactive waste, explosive waste, and electronic waste (e-waste).

Environmental costs: Inappropriately managed wastes can attract rodents and insects, which can harbor gastrointestinal parasites, yellow fever virus, worms, and the plague pathogen. Exposure to hazardous wastes, particularly when they are burned, can cause various other diseases including cancers (Diaz, 2006). Groundwater has been naturally very clean because of its filtering effect however, it can become polluted with nutrients and toxic chemicals when surface water carrying these substances drains into the groundwater environment (UNSD, 1997). Toxic waste materials can contaminate surface water, groundwater, soil, and air which cause more problems for humans, other species, and ecosystems (Diaz, 2006). Waste burning produces significant greenhouse gas (GHG) emissions, notably methane, which is contributing significantly to global warming (EPA, 2009). This can lead to flooding and many other environmental problems, thereby polluting water bodies.

Uzoigwe and Agwa (2011) assessed and compared the water quality of six selected bore holes used around dumpsite and non-dump site areas in Obio-Akpor and Ikwerre Local Government Areas, Port Harcourt. They identified that wastes at the state were disposed in a disorganized manner. Siting of drinking water system (wells

and boreholes) near a refuse dump site or landfill was discovered by the researcher as a danger associated with drinking water sources. Water analyses of the bio-physico-chemical variables, total coliform and feacal coliforms were done. Some water borne total heterotrophic bacterial count ranged from 3.7 $x10^5$ to 6.6 $x10^5$ cfu/ml and 3.1$x10^2$ to 4.4$x10^2$ cfu/ml for near dumpsite and non-dumpsite borehole water samples respectively while the total coliform count ranged from 47 to 1,100 most probable number (MPN /100ml) and 43 to 210 MPN/100ml for near dumpsite and non-dumpsite samples respectively were reported. In conclusion, the borehole water samples from both study areas had high counts of fecal coliforms (*Escherichia coli*), and pathogens (Salmonella, Shigella and Vibrio spp.) which were detected in high numbers in the water samples near dump site.

2.3.3 Market

A market is an actual or nominal place where forces of demand and supply operate, and where buyers and sellers interact (directly or through intermediaries) to trade goods and services, or contacts or instruments, for money or barter (Tucker, 2002). Various types of waste are generated from market, especially food wastes, paper, cardboard, plastics, textiles, rubber, leather, wood, glass, ferrous metals etc. For the developing countries waste management is a growing environmental and financial problem (Rahman *et al.,* 2013).

Ebna *et al* (2013) worked on the solid waste management strategy and improvement of existing scenario based on market waste. The study considered waste as never a good part of the environment, but sometimes useful when it is recyclable. Waste was also identified as a major problem due to poor management both in developing and developed countries. It was discovered that sustainable management for market solid waste is a concern in Khulna city to

lessen environmental pollution and odor nuisances which contribute to climate changes. The researcher investigated six markets, each which was said to contain about 13-15 tons of solid wastes which were generated per day by individual's in the markets. It was discovered that about 83% food waste, 6% paper, 5% plastics, 2%ferrous metals, 1.5% wood, 0.7% glass, 0.6% card board, 0.5% textiles, 0.4% rubber, 0.3% leather were produced as the total amount of wastes per day in each market. The study concluded that since more wastes are generated per day in each market therefore, adequate provision for economically sustainable waste disposal management, especially in selecting a suitable place for disposal should be a major concern of the government to ensure better human health and safety of workers.

2.4 Water Borne Diseases

Waterborne diseases are caused by pathogenic micro-organisms that are commonly transmitted in contaminated fresh water (WHO, 2002). Infection commonly results during bathing, swimming, washing, drinking, preparation of food, or the consumption of infected food. Various forms of waterborne diarrheal disease are the most prominent examples and affect mainly children in developing countries. According to the World Health Organization, such diseases account for an estimated 4.1% of the total disability adjusted life year (DALY) global burden of disease, and cause about 1.8 million human deaths annually. The World Health Organization estimated that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene (WHO, 2008).

In developing countries, particularly in Nigeria, the two main water problems man contends with are the quantity and quality of water (Olajuyigbe, 2010). In view of its occurrence and distribution pattern, water is not easily available to man at the desirable amount and quality. This is a problem experienced in most cities and towns in

the developing nations and particularly in rural settings. These factors have led to the growing rate of water borne diseases such as typhoid fever and cholera experienced in this part of the world (Edwards, 1993).

2.5 Water Borne Bacteria Pathogen

Bacteria are all around us, in the air, on objects and normally found in and on the human body. When bacteria are on the human body in the absence of disease, it is called a colonizer. However, infection could occur from pathogenic bacteria from food, water, abrasions and other wounds and even from colonizing bacteria if it gets into a sterile part of the body. A pathogenic bacterium is one that causes disease in the host. The list of pathogenic bacteria is quite large, but there are some that are common causes of disease in humans.

There are dozens of different species of Gram-negative bacilli, that could cause water borne disease as enumerated below;

2.5.1 Vibrio Cholerae

Vibrio cholerae also known as comma bacillus is a Gram negative comma-shaped bacterium with a polar flagellum. *V. cholerae* and other species of the genus *Vibrio* belong to the gamma sub-division of the Proteobacteria. The serogroups of *V. cholerae* are 01, 0139 and non-01. The biotypes of *V. cholerae* are cholerae (classical) and *el tor* which is further sub-divided into Ogawa, Inaba and, Hinkojima serotypes (Park, 2009).

2.5.1.1 Scientific Classification

Kingdom: Bacteria

Phylum: Proteobacteria

Class: Gama proteobacteria

Order: Vibrionalis

Family: Vibrionaceae

Genus: *Vibrio*

Species: *cholerae*

Binomial Name: *Vibrio cholerae* (Fillipo, 1854)

Vibrio cholerae was first isolated as the cause of cholera by the Italian Anatomist Filippo Pacini in 1854, but his discovery was not widely known until Robert Koch, working independently thirty years later, published the knowledge and the means of fighting the disease (Ryan and Ray, 2004). *Vibrios* are one of the most common organisms on the surface of waters of the world. They occur in both marine and fresh water habitats and in associations with fish and other marine life (Ryan and Ray, 2004).

2.5.1.2 Epidemiological Determinants of Cholera

i Pathogen Factors

a. Agent: The organism that causes cholera is labeled as *V. cholerae* O Group1 or *Vibrio cholera*e 01(WHO, 2002).
b. Resistance: *V. cholerae* is killed within 30minutes by heating at 56^0C or within a few seconds by boiling. They can remain in ice for 4-6weeks or longer. Drying and sunshine will kill them in a few hours. They are easily destroyed by colar-tar disinfectants such as cresol.

ii Host Factors

a. Age and gender: cholera affects all ages and both gender. In endemic areas, attack rate is highest in children. The elderly are also more susceptible to death from the disease.

b. Gastric acidity: this is an effective barrier. *Vibrio* organism is destroyed in an acidity of pH 5 or lower. Conditions that reduce gastric acidity may influence individual susceptibility (Park, 2009)

c. Population mobility: movement of population, for example pilgrimages, families, for fairs and festivals and other reasons have resulted in increased risk of exposure to infection and play a role by introducing cholera into new population.

d. Economic status: the incidence of cholera tends to increase in lower socio-economic groups, and this is attributed mainly to poor hygiene and also low standards of personal hygiene, lack of education and poor quality of life. Borroto and Martinez-piedra (2000) and Talavera and Perez (2009) identified poverty as an important predictor of cholera.

e. Immunity: Immunity to *V. cholerae* is mediated mainly by the local intestinal immune system. Vaccination gives only temporary and partial immunity for 3-6 months (Park, 2009).

iii Environmental Factors

a. Poor sanitation: *Vibrio* transmission is readily possible in a community with poor environmental sanitation. The lack of provision of waste dumps collection, adequate toiletry, and drainage facilities results in sickness and increases the risk of transmission. Also, bad sanitation practices in highly populated areas harboring the bacteria are the source of intermittent outbreaks due to contamination of drinking water and or improper food preparation.

b. Proximity and density of refuse dumps: According to Osei and Duker (2008), there is a direct linear relationship between cholera prevalence and refuse dumps density and an inverse relationship with proximity to refuse dumps. Flies such as *Musca domestica* can serve as a medium for the transmission of *V. cholerae* (Fotedar, 2001; Ojo, 2014).

c. Proximity to surface water bodies: Closeness to water bodies like river and stream can predispose people to cholera and also enhance the spread of cholera. Outbreak can occur when there is a heavy outpour of rain which can wash sewage into open wells and ponds where people obtain water for drinking and household needs.

d. Lack of clean drinking water: Typically, the world's poorest people obtain drinking water from a river/stream or wells due to lack of infrastructure and economic development. In the absence of toilet facilities or public sewage systems, people defecate near these rivers and streams thus allowing human waste to mix with the same water used for drinking (Jerry, 2012). Thus, this always makes people susceptible to cholera. Also, the health status of a population is dependent on the availability of water in sufficient quantity and at good quality especially in urban areas (Tessier, 1991). Access to clean water is a human right and is an essential determinant for good health, physical and social well-being (Kjellstrom *et al.,* 2007).

2.5.1.3 Mode of Transmission of *V. cholerae*

Transmission occurs via:

a. Contaminated water: Contaminated water sources such as wells, lakes, ponds, streams and rivers with free-living *V. cholerae* cells are the main source of cholera and it poses a great threat.
b. Contaminated food and drink: Ingestion of contaminated food and drinks has been associated with cholera outbreaks (WHO, 2002). Bottle-feeding could be significant risk factors for infants. Fruits and vegetables washed with contaminated water can be a source of infection. After preparation, cooked food may be contaminated through contaminated hands and flies (Gunn *et al.*, 1981).
c. Direct contact: In developing countries, a considerably proportion of cases may result from secondary transmission that is person to person transmission through contaminated fingers while carelessly handling excreta and vomit of patients and contaminated linens and vomits.

2.5.1.4 Symptoms of Cholera

The primary symptoms of cholera are profuse diarrhea and vomiting of clear fluid (Sack *et al.,* 2006). These symptoms usually start suddenly, half a day to five days after ingestion of the bacteria (Azman *et al.,* 2012). The diarrhea is frequently described as “rice water” in nature and may have a fishy odour. An untreated person with cholera may produce 10 to 20litres of fluid a day (Sack *et al.,* 2006). Severe cholera, without treatment, kills about

half of affected individuals through life-threatening dehydration and electrolyte imbalances. Cholera has been nicknamed the “blue death" because a person’s skin may turn bluish-gray from extreme loss of fluids (Ann and Patricia, 2014). Other symptoms include abdominal cramps, dry mucus membranes of the mouth, dry skin, excessive thirst, glassy or sunken eyes, lack of tears, lethargy, low urine output, nausea, hypotension, rapid pulse, sunken “soft spots” (fontanelles) in infants and unusual sleepiness or tiredness.

2.5.1.5 Laboratory Diagnosis of Cholera

The diagnosis of cholera can never be made without certainty on clinical grounds. Laboratory methods of diagnosis are required to confirm the diagnosis. Clinical specimen (stool, vomitus) are collected for isolation and identification of *Vibrio cholerae.* Water samples containing 1-3 liters of suspected water should be collected in sterile bottles or 9 volumes of sample water added to 1 volume of 10 percent alkaline peptone water and dispatched to the laboratory by the quickest method of transportation (Park, 2009).

2.5.1.6 Global and Regional Burden of Cholera

The World Health Organization (WHO) estimated that there are 5.5million cases of cholera and 120,000 deaths each year, mostly in Africa where epidemics have become more widespread and frequent (WHO, 2005). Cases were reported from all regions of the world, including 22 countries in Africa, 14 countries in Asia, 2 in Europe, 8 in the Americas and 1 from Oceania. Of the 26 countries that reported deaths from cholera, 17 were from the African continent accounting for 1366 deaths (case fatality ratio, CFR, 2.43%) or 65% of the global total, while in the Americas, the Dominican Republic and Haiti reported 635 deaths (CFR, 1.04%) or 30% of the global total.

Cholera has been very rare in industrialized nations for the last 100years while the disease is still common today in other parts of the world, including the Indian subcontinent and sub-Saharan Africa (WHO, 2012). In 2004, 56 countries officially reported to world health organization 101,383 cases of cholera and 2,345 deaths. Out of these, 407 occurred in Ghana with 6 deaths (WHO, 2005). The percentage of people who die from reported cholera cases remains higher in Africa than elsewhere. This reflects the lack of access to basic health care and basic facilities compared to the developed countries such as United States, because of advanced water and sanitation systems (WHO, 2010).

2.5.1.7 Burden of Cholera in Nigeria

In Nigeria, the first series of cholera outbreaks were reported between 1970 and 1990 (Lawoyin *et al.,* 1999). Although reports of cholera epidemic in Nigeria have not been consistent, the disease is very dynamic. The emergence of cholera was evident in 1970 and was re-introduced in 1991. During the last two decades, three major epidemics have occurred 1995, 1996, and 1997 (Huq *et al.,* 2003). Northern Nigeria has been known to be endemic for cholera infection. Epidemiological data from Public Health Department of Kano State Ministry of Health, revealed that the frequency and distribution of recurrent cholera epidemics in the state during 1995 to 2001, were 2,630 in 1995 and 1996, 847 in 1997 and 2, 347 in 1999 (Usman, 2005)

The 2010 outbreak of cholera and gastroenteritis plus the attendant deaths in some regions in Nigeria brought to the forefront the vulnerability of poor communities and most especially children to the infection because it was the largest epidemic in Nigeria since 1991 when 59, 478 cases and 7,654 deaths were reported (WHO, 2010). The outbreak started from north-eastern boarder state of Borno and spread to involve 18 of the 36 states of the country.

The outbreak was attributed to rain which washed sewage into open wells and ponds, where people obtain water for drinking and household needs (the regions ravaged by the scourge include Jigawa, Bauchi, Gombe, Yobe, Borno, Adamawa, Taraba, Federal Capital territory, Cross River, Kaduna, Osun and Rivers, depicts major outbreak locations). Even though the epidemic was recorded in these areas, epidemiological evidence indicated that the entire country was at risk, with the postulation that the outbreak was due to hyper-virulent strains of the organism (Gyoh, 2011). In 2012, 597 cases and 18 deaths (CFR 3%) in 29 LGAs in 11 states of Nigeria were recorded. More so, in 2014, 855 cases were reported with 20 deaths (CFR 3.3%) in 28 LGAs in 9 states of Nigeria (UNICEF, 2013).

2.5.1.8 Burden of Cholera in Osun State

In Osun state, no fewer than 70 persons were hospitalized at the Obafemi Awolowo University Teaching Hospital Complex (OAUTHC), Ile-Ife, following a cholera outbreak in Ife Central Local Government of Osun. Cholera outbreak also occurred at Ede North and South LGAs where 3persons died and 42 others were hospitalized (Fatiregun *et al.,* 2012)

Furthermore, a total of 23,377 cholera cases and 742 deaths (CFR 3.2%) occurred in Osun State in 2011. Also, the extreme rise in numbers of reported cholera in December 2012 (134 new cases, including 14 deaths, CFR 10.4%) resulted from an outbreak due to flood in Osun State (Adagbada *et al.,* 2012).

2.5.2 Other Water-Borne Pathogenic Bacteria of Importance

Most bacterial pathogens potentially are transmitted by water. Some bacteria communicate diseases and are discharged from the excreta of infected humans and other animals. Here are some other water-borne pathogenic bacteria of importance:

2.5.2.1 *Escherichia coli*

Escherichia coli are present in large numbers in the normal intestinal flora of humans and animals, where it generally causes no harm. However, in other parts of the body, *E. coli* can cause serious disease, such as urinary tract infections, bacteraemia and meningitis (Nataro *et al.,* 1998). One of the more common Gram-negative bacilli that cause disease in humans is *E. coli* (Forbe, 1998). The pathogens have been detected in a variety of water environments. Livestock such as cattle and sheep and, to a lesser extent, goats, pigs and chickens, are a major source. Also, *E. coli* have been associated with raw vegetables, such as bean sprouts. Infection is associated with person-to-person transmission, contact with animals, food and consumption of contaminated water. Person-to-person transmissions are particularly prevalent in communities where there is close contact between individuals, such as nursing homes and day care centers.

2.5.2.2 *Citrobacter freundii*

Citrobacter freundii belongs to the family of Enterobacteriaceae. *C. freundii* are commonly found in the environment, mainly in soil, water, and sewages. They are an indicator of potential contamination of water (Wang *et al.,* 2000). They are also found on different organs of diseased animals, including mammals, birds, reptiles, and amphibians (Wang *et al*., 2000). *C. freundii* represents approximately 29% of all opportunistic infections. It is known to be the cause of a variety of nosocomial infections of the respiratory tract, urinary tract, blood and several other normally sterile sites in patients (Whalen *et al.,* 2007).

2.5.2.3 *Citrobacter koseri*

This is a non-spore forming bacillus. It is a facultative anaerobe but capable of aerobic respiration. It is motile via peritrichous flagella. The members of this family are the part of the normal flora of human and animal digestive tracts (Ong *et al.,* 2010*). C. koseri* may act as an opportunistic pathogen in a variety of human infection. Occasionally, it causes meningitis, but it can cause sepsis, ventriculitis, and cerebritis with 80% frequent multiple brain abscesses in low-birth-weight, immuno-compromised neonates; rare cases have been reported in older children and adults (Babyn, 2011) and (Doran, 1999). The most effective way to reduce transmission of organisms is regular hand-washing (Babyn, 2011).

2.5.2.4 *Pseudomonas aeruginosa*

P. aeruginosa is an opportunistic human pathogen. It is "opportunistic" because it seldom infects healthy individuals (Botzenhardt and Doring, 1993). *P. aeruginosa* is a leading Gram-negative opportunistic pathogen at most medical center, carrying a 40-60% mortality rate. *P. aeruginosa* is a very ubiquitous microorganism that has been found to live on both inanimate and human environments such as soil, water, humans, animals, plants, sewage and sink inside and outside the hospital, swimming pools and whirlpools because the warm temperatures are favorable to its growth (Botzenhardt and Doring, 1993; Costerton and Anwar, 1994; Lederberg, 2000).

2.5.2.5 *Enterobacter*

Two clinically important species from this genus are *E. aerogenes* and *E. cloacae*. *Enterobacter* is a genus of Gram-negative, rod-shaped, non-spore-forming, motile bacteria of

the family Enterobacteriaceae. The urinary and respiratory tracts are the most common sites of infection. *Enterobacter* can be found on human skin and plants as well as in soil, water, sewage, intestinal tracts of humans and animals, and some dairy product. (Hoffmann and Andreas, 2003). Spectrum of *Enterobacter* infections include bacteremia, lower respiratory tract infections, skin infections, soft tissue infections, urinary tract infections, endocarditis, intra-abdominal infections, septic arthritis, osteomyelitis, and ophthalmic infections. They are opportunistic pathogens that rarely cause disease in otherwise healthy individuals.

2.5.2.6 *Klebsiella pneumoniae*

Klebsiella pneumoniae is found as a normal flora of the mouth, skin, and intestines (Ryan and Ray, 2004). It can cause destructive changes to human and animal lungs if aspirated (inhaled), specifically to the alveoli (in the lungs) resulting in bloody sputum. In recent years, *Klebsiella* have become important pathogens in nosocomial infections. As a general rule, *Klebsiella* infections are seen mostly in people with a weakened immune system. This patient population is believed to have impaired respiratory host defenses, including persons with diabetes, alcoholism, malignancy, liver disease, chronic obstructive pulmonary diseases, glucocorticoid therapy, renal failure, and certain occupational exposures (such as paper-mill workers). Feces are the most significant sources of patient infection, followed by contact with contaminated instruments. The range of clinical diseases includes pneumonia, thrombophlebitis, urinary tract infection, cholecystitis, diarrhea, upper respiratory tract infection, wound infection, osteomyelitis, meningitis, bacteremia and septicemia. Two unusual infections of note from *Klebsiella* are rhinoscleroma and ozena. Rhinoscleroma is a chronic inflammatory process involving the nasopharynx. Ozena is a chronic atrophic rhinitis that produces necrosis of nasal mucosa and mucopurulent nasal discharge.

2.5.2.7 *Proteus mirabilis*

This is a Gram-negative, facultatively anaerobic, rod-shaped bacterium. *P. mirabilis* causes 90% of all Proteus infections in humans. It is widely distributed in soil and water. This rod-shaped bacterium has the ability to produce high levels of urease, which hydrolyzes urea to ammonia (NH_3), so makes the urine more alkaline. If left untreated, the increased alkalinity can lead to the formation of crystals of struvite, calcium carbonate, and apattite, which can result in kidney stones. The bacteria can be found throughout the stones, and these bacteria lurking in the kidney stones can reinitiate infection after antibiotic treatment. Once the stones develop, over time they grow large enough to cause obstruction and renal failure. *Proteus* species can also cause wound infections, and pneumonia, mostly in hospitalized patients (O'hara *et al.*, 2000).

2.5.2.8 *Salmonella typhi*

Salmonella typhi is a Gram negative bacterium that causes systemic infections and typhoid fever in humans. It is a rod-shaped, flagellated organism which sole reservoir is humans. It has caused many deaths in developing countries where sanitation is poor and is spread through contamination of water and undercooked food (Humphrey-Tom, 2004). *S. typhi* cause over 60,000 deaths annually all over the world (Den *et al.,* 2003). It causes the disease called typhoid fever. It has caused epidemic in South Africa where sanitation was lacking (Den *et al.,* 2003). *S. typhi* usually invades the surface of the intestine in humans, but has adapted to grow into the deeper tissue of the spleen, liver, and bone marrow. Symptoms most characterized by this disease often include a sudden onset of a high fever, a headache, and nausea. Other common symptoms include loss of appetite, diarrhea, and enlargement of the spleen. Some individuals who are infected with *S. typhi* become life-long carriers that

serve as the reservoir for these pathogens. *S. typhi* has an endotoxin (which is typical of Gram negative organisms), as well as V1 antigen, which increases virulence (Falkow *et al.,* 2004).

2.5.2.9 *Shigella dysenteriae*

S. dysenteriae is a species of the rod-shaped bacteria genus Shigella (Ryan and Ray, 2004). *S. dysenteriae* spread by contaminated water and food, causes the most severe dysentery because of its potent and deadly shiga toxin, but other species may also cause dysentery (Herold *et al.,* 2004). Flies have also been identified as a transmission vector from contaminated fecal waste. The disease caused by *Shigella* is called shigellosis (Bacillary dysentery). The most commonly observed signs associated with Shigella dysentery are colitis, malnutrition, rectal prolapse, tenesmus, reactive arthritis, and central nervous system abnormalities. Furthermore, *S. dysenteriae* is associated with the development of hemolytic uremic syndrome, which includes anemia, thrombocytopenia, and renal failure (Hale and Keusch, 1996). Humans and other higher primates appear to be the only natural hosts for Shigella. The bacteria remain localized in the intestinal epithelial cells of their hosts. Transmission is often caused by bacteria on unwashed hands during food preparation, or soiled hands reaching the mouth. A number of large waterborne outbreaks of shigellosis have been recorded. As the organisms are not particularly stable in water environments, their presence in drinking-water indicates recent human fecal pollution. The control of *Shigella* spp. in drinking-water supplies is of special public health importance in view of the severity of the disease caused. (Pegram *et al.,* 1998)

2.6 Transmission of Water-Borne Diseases

Water-borne diseases spread by contaminated drinking water systems mixing with feces and urine of infected animals or people, runoff or floodwater, landfills, sewer pipes,

septic fields, industrial or residential developments. The spread of diseases is likely to happen where private and public drinking systems such as surface water creeks, rivers, lakes, and rain are contaminated. There are a number of additional ways in which fecal material may reach a person's mouth such as in food that is contaminated, or the person's hands. Generally, eating contaminated foods and drinking contaminated water are some of the most common ways people become infected. The germs in feces may cause the diseases at the slight contact and transfer (Okpara, 2000). Waterborne outbreaks of enteric disease have occurred either when public drinking water supplies were not adequately treated after contamination with surface water or when surface waters contaminated with enteric pathogens have been used for recreational purposes (Johnson *et al.,* 2003).

2.7 Prevention of Water-Borne Diseases

Although an increasing number of households are securing water supplies but securing water of good quality is a challenge (EPA, 2005). The approach to break continued transmission of water-borne diseases is to improve the hygienic behavior of people and provide them with basic needs such as awesome drinking water, bathing and washing facilities (WHO, 2013). It is also well recognized that the prevalence of water-borne diseases may be greatly reduced by providing people with safe, sanitary disposal of feces and refuses. Water can be disinfected to kill any pathogen that might be present in the water supply and to prevent them from growing again in distribution systems in order to protect people's health. Disinfection is important because without it, the risk of water borne diseases increases **(**UNWWDR, 2014). The two most common methods of killing microorganisms in the water supply are irradiation with ultra-violet radiation or oxidation with chemicals like chlorine dioxide, ozone or chlorine (WHO, 2004).

2.8 Geographic Information System

A geographic information system (GIS) is an integrated suite of computer-based tools which facilitates the input, processing, display, and output of spatially referenced data (Burrough and McDonnell, 1998).

2.8.1 History of Geographic Information System

GIS started in 1854 when Cholera hit the city of London, England. John Snow's cholera study (1854) served as a good example of how geographic mapping could provide new insights into communicable-disease etiology and intervention, helping disease control efforts. In his study, he used a spot map to illustrate how cases of cholera were centered on the pump. He also made a solid use of statistics to illustrate the connection between the quality of the source of water and cholera cases. He achieved his findings by mapping out the locations of individual water pumps and generated cells which represented all the points on his map which were closest to each pump. He also examined water samples from various wells under a microscope and confirmed the presence of an unknown bacterium in the Broad street samples. He had the pump handles removed from the Broad street pump and the outbreak quickly subsided. Then a map of the epidemic to support his findings was produced which included the locations of the 13 public wells in the area and the 578 cholera deaths mapped by home address. In conclusion, the section of Snow's map representing areas in the city where there were death were the areas which available source of water was from the Broad street pump. Although his map alone did not determine the cause of the 1854 cholera epidemic, it served as a useful tool to summarize his findings and convince his contemporaries of his conclusions.

It was a major event connecting geography and public health safety. Not only was this the beginning of spatial analysis, it also marked the start of a whole field of the study of Epidemiology.

2.8.2 The GIS Data Models

This allows the geographic features in real world locations to be digitally represented and stored in a database so that they can be abstractly presented in map (analog) form, and can also be worked with and manipulated to address some problems. All spatial data models fall into two categories - Raster and Vector

Vector: This is a coordinate based data model that represents geographic feature as points, lines and polygons.

Raster: This is a spatial data model that defines space as an array of equally sized cells arranged in rows and columns and composed of single or multiple bands. Almost all raster data are images for example satellite images.

2.8.3 Spatial Analysis

This is the process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques in order to address a question or gain useful knowledge. Spatial analysis extracts or creates new information from spatial data. A dictionary of geography and Oxford University press 2005 defined spatial analysis as a type of geographical analysis which seeks to explain patterns of human behavior and its spatial expression in terms of mathematics and geometry, that is, location analysis. Spatial analysis is a set of techniques for analyzing spatial data**.** The results of spatial analysis are

dependent on the locations of the objects being analyzed. Software that implements spatial analysis techniques requires access to both the locations of objects and their attributes.

2.8.4 GIS Spatial Analysis Tool

Buffering

A buffer is a zone around an object, such as a school or intersection that has some investigative or analytical significance. A buffer in GIS is a zone around a map feature measured in units of distance or time. A buffer is an area defined by the bounding region determined by a set of points at a specified maximum distance from all nodes along segments of an object. A buffer is a reclassification based on distance: classification of within/without a given proximity.

A buffer is useful for proximity analysis (Wade and Sommer, 2014). Buffering involves measuring distance outward in directions from an object. Buffering can be done on all three types of vector data: point, line and area. The resulting buffer is a polygon file. Most often, buffers are measured in uniform distance, for example, by creating a 50meters buffer around all rivers. A buffer based on different distances is called a variable buffer. For example, the noise level surrounding a street network may be based on the traffic load. Therefore a variable buffer may be used to illustrate the noise level by using a larger distance for high traffic roads and a shorter distance for quiet roads.

For polygons that are buffered, there are two additional types of buffers.

Bidirectional buffers are polygons that are buffered from the boundary outwards as well as inwards. Setback buffers are polygons that are only buffered from the boundary inward. The distance a buffer should be around a GIS feature is dependent upon the need: Arbitrary buffers measure values with a gut feelings; Causative buffers measure values with a prior

knowledge; Measurable buffers measure values such as a view shed while mandated buffers measure values with a predefined values for example: 1000meters ordinance around schools (Burrough and McDonnell, 1998).

2.8.5 Geographic Information Science and Spatial Analysis

Geographic information systems (GIS) and the underlying geographic information science that advances these technologies have a strong influence on spatial analysis. Geographic data capture systems include remotely sensed imagery, environmental monitoring systems such as intelligent transportation systems, and location-aware technologies such as mobile devices that can report location in near-real time. GIS provide platforms for managing these data, computing spatial relationships such as distance, connectivity and directional relationships between spatial units, and visualizing both the raw data and spatial analytic results within a cartographic context.

Geo-visualization combines scientific visualization with digital cartography to support the exploration and analysis of geographic data and information, including the results of spatial analysis or simulation. Geo-visualization leverages the human orientation towards visual information processing in the exploration, analysis and communication of geographic data and information. In contrast with traditional cartography, Geo-visualization is typically three- or four-dimensional (the latter including time) and user-interactive.

2.8.6 GIS for Public Health

Today's public health problems are much larger in scope than those Dr. Snow faced, and researchers today depend on modern GIS and other computer mapping applications to

assist in their analyses (Center for Disease Control and Prevention, 1990). Public health efforts fall naturally within the domain of problems requiring the use of spatial analysis as part of the solution. GIS and other spatial analysis tools are therefore recognized as providing potentially transformational capabilities for public health efforts.

Public health informatics is an emerging specialty which focuses on the application of information science and technology to public health practice and research (Hanchette *et al.,* 2003). As part of that effort, a GIS – or more generally a spatial decision support system offers improved geographic visualization techniques, leading to faster, better, and more robust understanding and decision-making capabilities in the public health arena (Yasnoff *et al.,* 2003)

Geographical Information System can support public health in different ways as well. First and foremost, GIS displays can help inform proper understanding and drive better decisions. For example, elimination of health disparities is one of two primary goals of "Healthy People 2010", one of the preeminent public health programs in existence today in the US. GIS can play a significant role in that effort, helping public health practitioners identify areas of disparities or inequities, and ideally helping them identify and develop solutions to address those shortcomings. GIS can also help researchers integrate disparate data from a wide variety of sources, and can even be used to enforce quality control measures on those data. Much public health data is still manually generated, and is therefore subject to human-generated mistakes and miscoding. For example, geographic analysis of health care data from North Carolina showed that just over 40% of the records contained errors of some sort in the geographic information (city, county, or zip code), errors that would have gone

undetected without the visual displays provided by GIS (Hanchette *et al.*, 2003). Correction of these errors led not only to more correct GIS displays, but also improved all analyses using those data.

2.8.6.1 Spatial Epidemiology

This is a subfield of health geography that focuses on the study of the spatial distribution of health outcomes. Specifically, spatial epidemiology is concerned with the description and examination of disease and its geographic variations (Elliot and Wartenberg, 2004).

TYPES OF STUDIES

DISEASE DIFFUSION MAPPING

Mapping and field surveys are the most commonly used techniques in health, simply translating the patient's addresses into longitudes and latitudes to pin point their location on earth.

GIS maps: Once all of the desired data have been entered into a GIS system, they can be combined to produce a wide variety of individual maps, depending on which data layers are included. Disease maps are visual representations of intricate geographic data that provide a quick overview of said information. Mainly used for explanatory purposes (Lawson and Dension, 2002).

Disease diffusion occurs when a disease is transmitted to a new location. It implies that a disease spreads, or pours out from a central source. The goals of disease mapping are to:

1. describe the spatial variation in disease incidences to formulate an etiological hypothesis
2. identify areas of high risk in order to increase prevention and to help in resource allocation in said areas.
3. provide a map (a symbolic depiction highlighting relationships between elements of some space, such as objects, regions and themes) which helps to solve health problems.

2.8.7 Applications of GIS in Health

A major goal of epidemiology is unraveling the causes of diseases and the ways in which they can be modified so as to assist in their control and prevention, ultimately leading to the promotion of good health (Beaglehole and Bonita, 2008). Epidemiologists have traditionally used maps when analyzing associations between location, environment, and disease. GIS has been used in the surveillance and monitoring of vector-borne diseases, water-borne diseases, in environmental health, analysis of research hypotheses, identification of high risk health groups, planning and programming of activities, and monitoring and evaluation of interventions (Carter, 1992).

Jerry (2012) identified that particular concern is the work on spatial analysis of cholera, whereby he worked on spatial distribution of cholera incidences and its associated environmental risks factors. The work identified sanitation as a key environmental factor which predisposes persons to cholera infection. In this study, the two identified important measurements of sanitation in an urban city, Kumasi are: proximity to refuse dumps and water reservoirs within a community. The results showed that there is an inverse spatial relationship between cholera prevalence and proximity to both refuse dumps ($p < 0.0001$) and classified reservoirs ($p < 0.001$). Then finally, a probability and risk maps were generated to characterize the spatial patterns of cholera prevalence in the Kumasi metropolis.

Palaniyandi and Maniyosai (2014) worked on Geo-spatial analysis of vector borne diseases transmission and the environment using remote sensing and GIS in India. These studies were conducted on the appreciation of remote sensing and GIS applications to the study of vectors' biodiversity, vector presence, vector abundance and the vector-borne diseases with respect to space and time. They collected data pertaining to vector borne diseases and attached it to the district map using Arcview 3.2 GIS platform (Environmental Systems Research Institute (ESRI) for preparation of diseases prevalence in India. Remote sensing of Internal Revenue Service Low Intensity Steady State (IRS LISS I and LISS II) data products were analyzed, using Earth Resources Data Analysis Systems (ERDAS) Imagine 8.5 and was integrated into GIS for spatial analysis for classification. The result shows the possible information on reliable estimates of mapping of malaria, filariasis, JE, and dengue vector breeding habitats, and facilitates the estimation of the people at risk of vector borne disease transmission and also shows that spatial agreement existed between the environmental variables and the vector borne disease epidemic transmission. This study shows that the application of remote sensing, GIS and GPS are effectively useful for detection, identification,

delineation and mapping of vector mosquitoes potential breeding surface areas and other vector borne diseases and also provides meaningful spatial solutions to control and manage vector borne diseases transmission based on the information derived from the geo-statistical analysis of environmental variables.

In review of other related work, Olajuyigbe *et al.,* (2012) utilized GIS techniques to investigate the spatial variation of water borne diseases in Ile-Ife, Nigeria. Primary data utilized for the study were; water samples which checked for the microbial count, pH and water hardness from water samples. Questionnaires were analyzed to determine the socio-economic characteristics of the households. The result of the water samples were interpolated on ArcGIS 9.3. The secondary data adopted include the land use data and reported cases of water borne diseases from health facilities, and geo-coding technique of ArcGIS 9.3 was employed to match the addresses of the patients with the cases of water borne diseases. The results showed that most reported cases of water borne diseases were due to environmental factors including poor environmental sanitation and topography. The study concluded that continuous negligence and under estimation of the role of water borne diseases may increase the vulnerability and health risk of the people in the area.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Area

Osun State is an inland state in south-western Nigeria. Its capital is Osogbo. Ile-Ife is one of the major towns in Osun State. Geographically, Ile-Ife is located between Latitude 07^0 $28^{'}$N and 07^0 $45^{'}$N and Longitude 4^0 $30^{'}$E and 4^0 34'E (Ajala and Olayiwola, 2013). The climate is tropical. Like every other Southwest area, the raining season extends from April to October

while the dry season lasts November to March. Ile-Ife has two major local governments namely Ife Central and Ife East.

Ife East LGA has an area of 172km ^{2} while Ife Central LGA has an area of 111km^2. The town has been witnessing population and physical growth (Ajala *et al*., 2001). The LGAs populations have tremendously increased over time. Ife East population was 188,087 as at the 2006 census while that of Ife central population was 167,254 as at 2006. In order to study the population growth of the LGAs over time, the populations, according to National Census Population Commission, were examined which include for the year 1991 and 2001; the population at Ife East LGA was 95,877 and that of Ife Central was 96,580 in the year 1991 while in the year 2001, using the growth rate of 3.5 percent by Ajala *et al.,* (2001), the population has tremendously increased to 135,216 in Ife East while that of Ife Central was 136,236 (Figure 3.1).

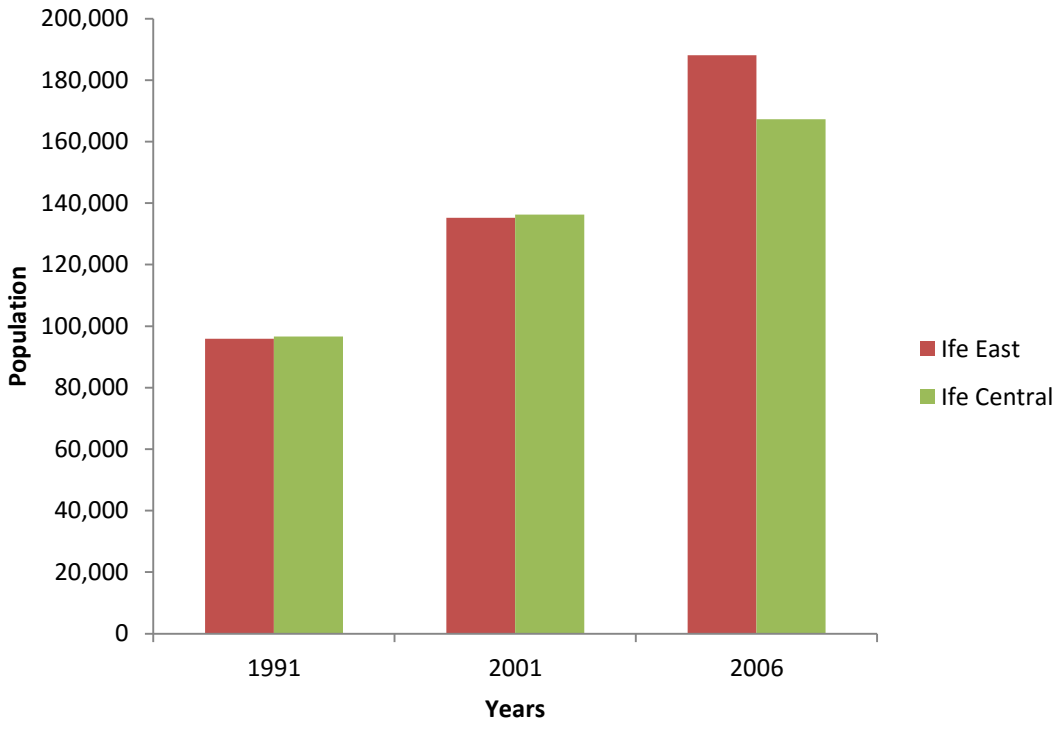


Figure 3.1: Population Increase in Ife East and Ife Central LGAs of Ile-Ife for the Year 1991, 2001 and 2006

As a result of such growth, many abattoirs were created because the meat needs of people are on the increase and more waste dump sites were generated. This study was carried out in Ife East and Ife Central Areas of Ile-Ife (Figure 3.2). The geographical locations of the sampling points were recorded (Appendix V).

3.2 Data Acquisition

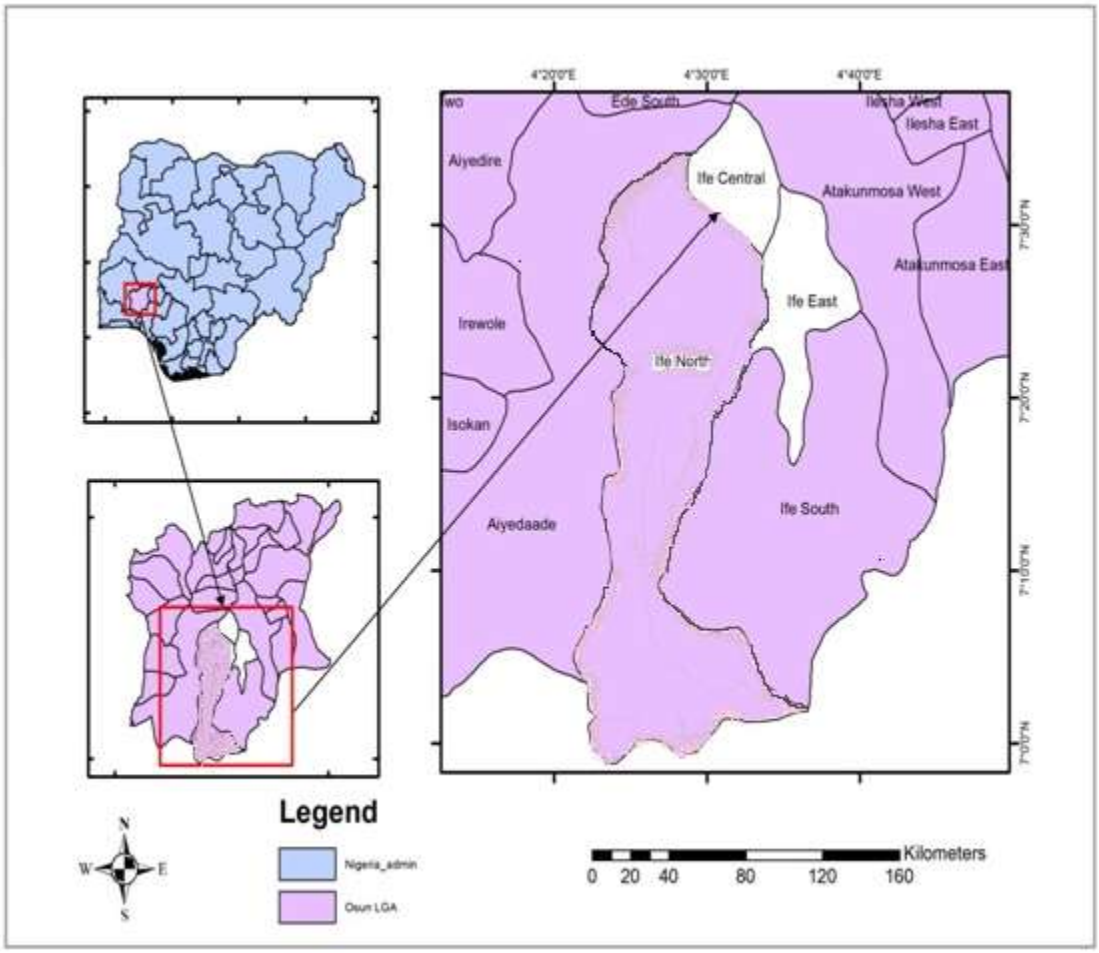
3.2.1 Primary Data

a. Global positioning system (GPS) was used to collect data on environmental risk factors (waste dump site, abattoir and market) in the study areas from May to June, 2015. The environmental risk factors were selected based on WHO predisposing factors to cholera (WHO, 2012). Hence, waste dump site, abattoir and market were selected for this study.

b. Coordinates of risk sites; abattoirs, waste dump sites and markets (the three prominent environmental risk factors in respect of cholera in the study area were geo-coded and plotted on a high resolution satellite imagery (Google earth), and land-use map of the study area for cross examination and visualization using ARCGIS software version 10.1.

c. Streams, rivers, buildings and roads were digitized. These digitized elements served as other risk factors (vulnerable elements) towards cholera.

Figure 3.2: Map of the Study Area



d. Spatial analysis was carried out to stratify the areas into different environmental risk zones by first creating a buffer zone around each of the environmental factors and then overlapping or superimposing the buffers of those sites on one another using ARCGIS software version 10.1.

Weights were assigned to the superimposed buffer zones, based on the interaction of the risk sites, using the intersection between the rings, thereby arriving at the following eight zones: abattoir only (zone one), market only (zone two), abattoir and waste dump site (zone three), abattoir and market (zone four), waste dump site and market (zone five), waste dump site, abattoir and market (zone six), waste dump site only (zone seven), and the eighth zone is the one outside the rings overlap (Figure 3.3).

e. Water samples were collected from well and surface water within each zone (July and August, 2015) for the estimation of total bacteria count (colony forming unit count), most probable number of organism (coliform bacteria count) and bacteria identification.

f. Structured questionnaire was administered to gather information on the level of environmental sanitation practices among selected people in the zones. The copies of questionnaire administered were based on the total numbers of environmental risk factors identified in the study area. Hence, eighty-one ERFs were located out of the ninety-four ERFs identified for this study. The method for the questionnaire administration at the various sites was in the form of an interview with the establishment representative or head. In the case of waste dump sites, a nearby house-head was approached to elicit information concerning the site. The questions asked were selected from WHO guideline (WHO, 2004 and Ramond, *et al.,* 2012).

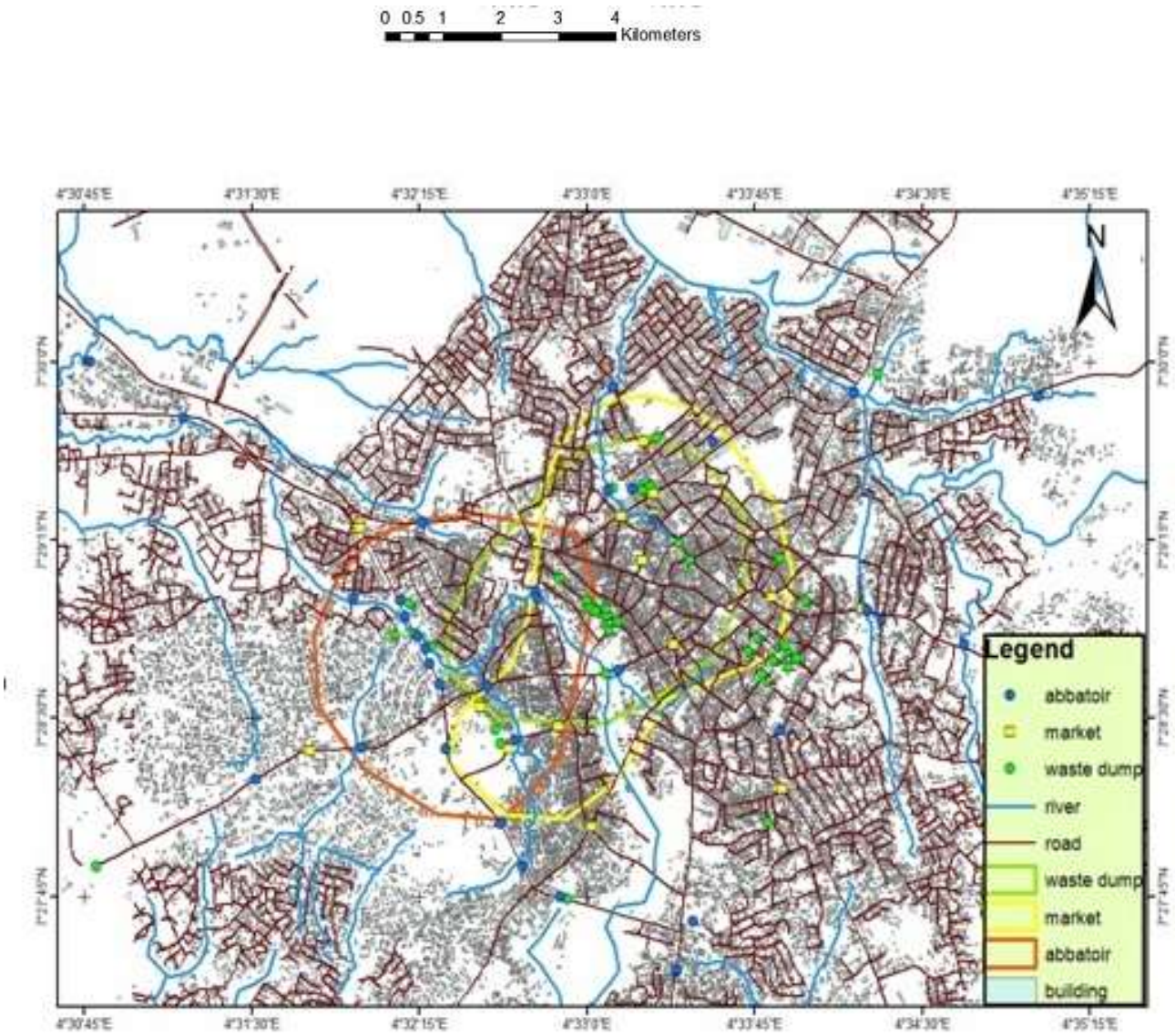


Figure 3.3: Stratified Environmental Risk Factors.

g. Site assessment was also done by the researcher to affirm the information that was gathered.

3.2.2 Secondary data

a. recent high resolution image (Google earth), land-use/land-cover map of the study area were used.

b. cholera incidence data were obtained from Ife East and Ife Central Monitoring and Evaluation Department for the year 2010 and 2011 which were the only cholera outbreak reported in the Local Government Areas. The months recorded for the incidences were; August, September and October. The main variable extracted from this data was the address of cases. By using the individual case addresses, all cases were located and coordinated using the Global Positioning System (GPS) handheld device. In the case whereby the address could not be located, the nearest common point in that area was taken as the point of coordinate.

c. The cholera incidence data, recent high resolution image, land-use/land-cover map of the study area and the sampling points were plotted on ARCGIS for cross examination and visualization.

3.3 Bacteria Identification

3.3.1 Sample Collection and Transportation

A purposive sampling technique was used to determine where water samples were gotten, thou the sampling was based on the proximity to the ERFs identified for this study. Hence, ten water samples were collected from zone one while ten, four, three, fourteen, six, four and eight were collected from zone two, three, four, five, six, seven and eight respectively. Therefore, a total number of 59 water samples were collected for this study. Thirty-six water samples were collected from wells while twenty-three water samples were collected from streams. Water samples for microbial

analysis were collected in sterile universal bottles. The samples were kept in an ice pack, transported to the laboratory immediately and some that were not used immediately were kept in the refrigerator to prevent contamination, this was done according to Golterman *et al.*, (1978) and WHO (1997) methods for water analysis. Water samples were collected in the morning within the period of 0630 hour to 0830 Nigerian local standard time. The period for the collection and the laboratory analysis lasted from July to August, 2015. The laboratory analysis of the water samples for *Vibrio cholerae* was done thrice for quality assurance sake.

3.3.2 Sample Processing

i Coliform Bacterial Count (MPN/ml)

This method, also known as the method of poisson zeroes, is a method of obtaining quantitative data on concentrations of discrete items from positive to negative (incidence data).

Procedures: Sufficient amount of MacConkey broth was weighed for the single, double strength and for the dilution. Five of the double strength MacConkey broth tubes were inoculated with 10ml of water sample, five single strength tubes with 1ml of water sample and five single strength tubes with 0.1ml of the water sample. The three sets of tubes were incubated at 35^0C for 48hours (WHO, 1997)

Result and interpretation: The positive tubes were counted, recorded and read by standard MPN reading guideline by WHO to ascertain the most probable number of organisms (WHO, 1997).

ii. Total Bacteria Count (CFU/100ml)

This was used to determine the number of viable bacterial cells in a sample per milliliter, while a colony represents an aggregate of cells derived from a single progenitor cell. Hence, it tells the degree of contamination in samples of water, soil and the magnitude of the infection in humans and animals.

Procedures: Sterile distilled water was placed in test tubes representing the dilution from 10^{-1} to 10^{-10}, serial dilution was done by introducing the samples in the correct proportion to the sterile distilled water. Serial dilutions of 10^{-4}, 10^{-5}, and 10^{-6} were chosen. Furthermore, 1ml each of the dilution was poured in the plates and prepared blood agar medium was poured into it. It was thereafter evenly spread throughout the plates (Cheesbrough, 2006)

Result and interpretation: The plates were thereafter incubated at 37^{o}C for 24 hours after which the colonies were counted and recorded. The degree of contamination of water samples were ranked according to Monica specification (Cheesbrough, 2006).

3.4 Isolation and Biochemical Characterization of Bacteria

i. Culture on MacConkey agar, alkaline peptone water and Thio-sulphate Bile Salt

Sucrose (TCBS): For the isolation of bacteria, positive samples in the test tubes were selected for culturing. Appropriate amount of MacConkey agar was weighed solubilized, poured in Petri dish and dried. The positive isolates were then streaked on the agar plate and incubated at 35^{o}C for 24 hours.

Alkaline peptone water was prepared and used for the enrichment of *Vibrio cholera*e in water samples. The 2% Sodium chloride in this medium promoted the growth of *Vibrio cholerae,* while the alkalinity of this medium inhibited most of the unwanted background

flora. Furthermore, 5ml of alkaline peptone water was poured into each of the McCartney bottles and 1ml of the water sample was added to each bottle, then they were incubated for 24 hours. Thereafter, adequate amount of Thiosulphate Citrate Bile Salt Sucrose (TCBS) was poured into the Petri dishes and then the samples in the alkaline peptone water was inoculated into the TCBS plates and incubated for 24 hours. The procedures used for the identification of *Vibrio cholerae* for this study was according to Theron *et al.,* (2000).

ii. Morphological identification on culture plates: Examination of the colonies on the MacConkey agar was done; the lactose fermenters gave a pink colony. Yellow colonies of 2mm were checked for on the TCBS media.

iii. Subculturing on nutrient agar: A pure colony on the media were aseptically picked and then sub-cultured into a nutrient agar to further identify the organisms.

v. Gram stain reaction: Cell arrangement, shape, and Gram reaction were the parameters used for the assessment of the gram staining process. A loop ful of normal saline water was picked by the use of a sterile inoculating loop, and dropped on the sterile micro-slides which were labeled with each isolate code. A colony was then picked aseptically from each plate, a smear was made on the slides. The slides were air dried and then heat dried with bursen flame. Afterward, crystal violet was added to the stained smears for 1minute and then rinsed off in gently running tap, Lugol's iodine for 1minute and rinsed off, acetone which served as a de-colourizer was added for 30seconds and rinsed off, safranin which served as a counterstained was added for 30seconds and also rinsed. Thereafter, the slides were allowed to air dry and then observed under oil immersion objective of the light microscope. The Gram negative bacteria appeared red, or pink in color and Gram positive bacteria appeared purple or blue black.

vi. Biochemical Identification Scheme: The test carried out on each isolate included the following: Sulphate Indole Motility (SIM), Triple Sugar Iron (TSI), citrate utilization test, urease test and oxidase test. The results were interpreted using Bergrey's manual of determinative bacteriology (1994).

a. Triple Sugar Iron: This is a microbiological test roughly named for its ability to test microorganism's ability to ferment sugars and to produce hydrogen sulfide. Each isolates was aseptically streaked on sterile Triple Sugar Iron (sucrose, lactose and glucose) agar slants in the test tubes using sterile inoculating loop. The butt was stab inoculated with the inoculums using sterile inoculating needle. The cultured tubes were incubated at 35^0C for 24 hours and observed for acid, gas and hydrogen sulfide (H_2S) production. The positive result will give a colour change from pink to yellow while there will be no colour change for the negative result. Black colouration will be observed for H_2S production while negative will give no colouration. Also, a positive result for gas production will give a space in the test tubes while no space is for the negative result.

b. Sulphide-Indole-Motility: This was employed to determine the ability of isolates to breakdown the amino acid tryptophan by secreting the enzyme trytophanase and to identify and distinguish the motile from non-motile bacteria. The S.I.M media were aseptically stab inoculated, using sterile inoculating needle, and then incubated at 35^0C for 24 hours. Then, they were examined for motility and hydrogen sulphide production. For indole production; 1ml of chloroform was added to each test tube, and after 15 minutes, few drops of Kovac's reagent was added, agitated and then examined for red color as an indication for the presence of indole production.

c. Citrate Ultilization Test: This was used in the identification of some members of the family enterobacteriaceae. It is based on the ability of the test isolate to utilize citrate as the sole source of carbon. Adequate proportion of Koser's citrate medium was poured into Bijou bottles and was inoculated using sterile straight wire with the test isolate and then incubated at 35^0C for 24 hours and observed for color change. A positive test will result in a colour change Green to Blue while a negative (-ve) result will be an absence of colouration.

d. Urease Test: This test is used to differentiate organisms based on their ability to hydrolyze urea with the enzyme urease. It is also used as part of the identification of several genera and species of Enterobacteriaceae, including Proteus, Klebsiella, some Yersinia and Citrobacter species, as well as some Corynebacterium species and many other bacteria that produce the urease enzyme. It was incubated at 35^oC for 48hours. Positive result gave a colour change from yellow to pink while a negative result appeared in its initial colour.

e. Oxidase Test: This test was used to determine if a bacterium produces certain cytochrome oxidase. Loops were wet with de-ionized water, then, a pure colony was transferred aseptically into a filter paper soaked with the substrate tetramethyl-p-phenylenediamine dihydrochloride. The filter paper was observed for color changes. If the area of inoculation changed colour, then the result is positive. If a color change does not occur within three minutes, the result is negative. A positive test (OX+) will result in a color change to deep blue or purple, within 10-30 seconds, while a negative test (OX-) will result in an absence of colouration.

3.7 Conceptual and Statistical Analyses

The geo-referenced cholera cases were plotted on the database map. The distance of each environmental risk zones to the cholera incidences was geo-visualized to check the proximity (relationship) between them. The result was presented in the form of a map. Also, proximity analysis which required a buffering of 300meters from the environmental risk factors to the historical cholera incidences was done with ArcGIS software 10.1. The result of the *Vibrio cholerae* and other pathogenic bacteria count per sample were used to build up the attribute for each of the water sample points on GIS map. The level of contamination was displayed on the map and integrated with the cholera database to produce an environmental risk map for the study area. The highest CFU count was given > 100, followed by 10.1-100, while the lowest count was given the range of 1 to 10 **(**WHO, 1997 and Cheesbrough, 2006). Spatial analysis was performed to stratify the areas into different disease hot spot density from very high to very low. Descriptive and inferential statistics (Chi-square) was used to interpret the questionnaire. Inferential statistics (Chi-square) was used to determine the association between different variables in the study. All statistics were discussed at 95% confidence level ($p < 0.05$)

CHAPTER FOUR

RESULTS

4.1 Environmental Risk Factors Associated with Cholera in the Study Area

The different rings with intersections depict areas of highest densities of each of the risk factors. The red ring depicts a zone of high concentration of abattoirs, while the yellow ring depicts zones of highest concentrations of markets and the green zone represents areas with highest concentrations of waste dumps. The various overlaps between abattoir and market, abattoirs and waste dump and waste dump and markets are zones of interactions among the factors. Another zone, which is central to all the rings, depicts areas of intersection among abattoir, market and waste dumps. The other zones that fall outside the rings are areas of low density of environmental risk factors. The rivers and streams flowed through all the designated areas of the environmental risk factors (ERFs). Most of the abattoirs were located around the streams and rivers. On the whole, the total number of abattoirs identified for the purpose of this study was 36, waste dump site had the total of 44 and the least was market which is 18 in number (Figure 4.1). Almost all the ERFs had being in existence for over 30 years and some indigenous areas were found close to these ERFs which had been in existence before 1960's.

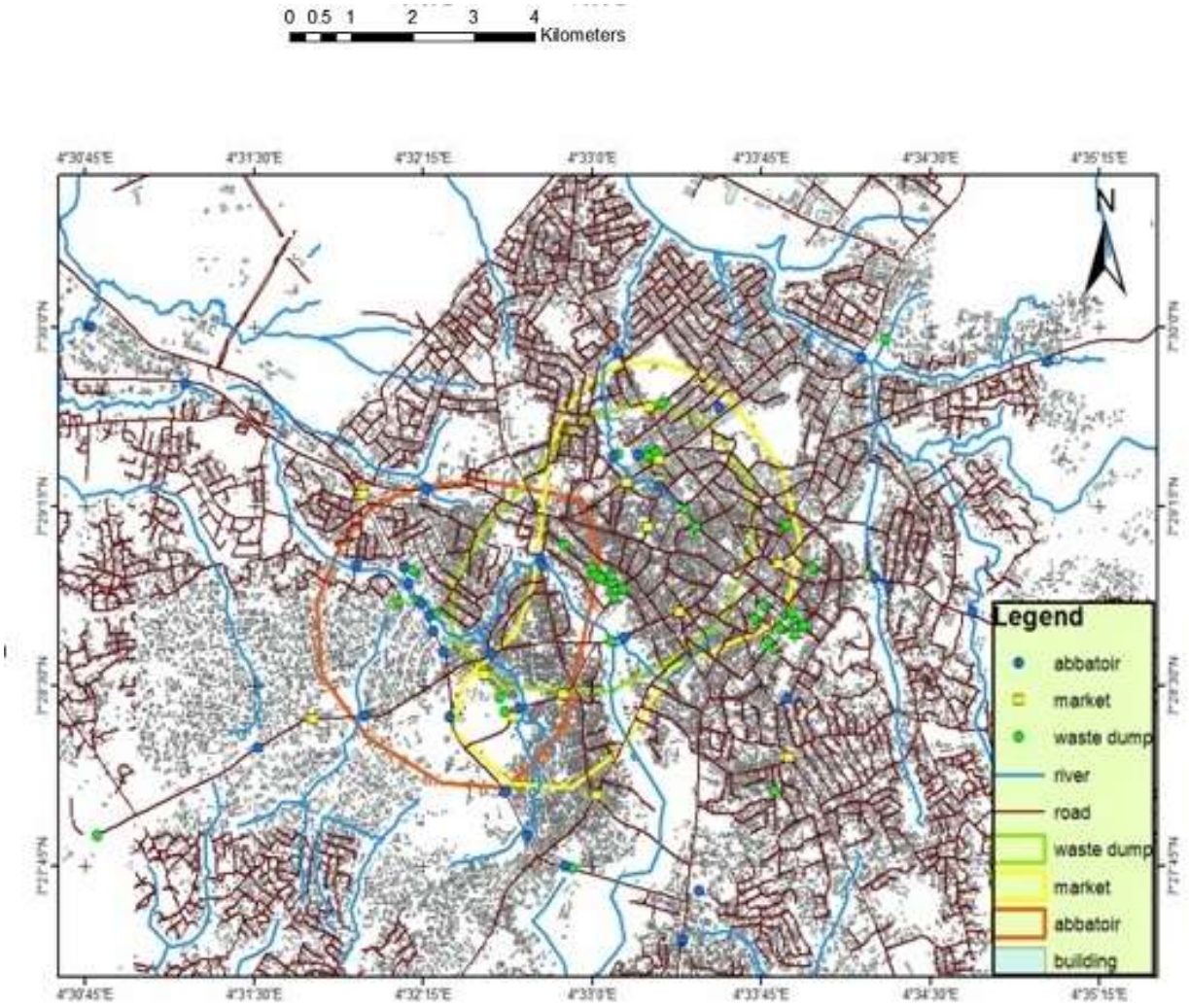


Figure 4.1: Sites of Identification of the Environmental Risk Factors.

4.2 Spatial Relationship between Cholera Incidences and Environmental Determinants of Cholera

Spatial analysis of 300 meters buffer showed the different hot-spots for cholera incidences. It was observed that 18 out of the 44 waste dump sites located in this study were near the historical cholera cases. These areas are Sabo 1, Sabo 2, Sabo 3, Ojoyin 3, Ojoyin 4, Ojoyin, Ayegbaju, Ayegbaju 2, Ilode, Ajamopo, Ilelami compound, Ilelami, Oke-Atan, Ayetoro/Iloro, Ajamopo 2, Esinmirin, Otutu, and Odi-Olowo. Similarly using the same approach, 7 out of the 18 markets in the study were observed to be near the historical cholera incidences and these areas are Oja Ife, Oja tutun market, Itakogun market, Iso obi market and Oduduwa street market. Finally, Sabo abattoir, and Oduduwa Street abattoir were the two (2) abattoirs selected out of 36 abattoirs that were found to be proximal to the historical cholera cases (Table 4.1 and Table 4.2).

The previous occurrences of cholera in Ife East and Ife Central LGA in the year 2010 and 2011 can be traced to the presence of market which contained bulk of waste dump sites proximate to the residential areas. Nineteen (19) historical cholera cases were identified in this map. Using geo-visualization, the map reveals that the historical cholera cases from 5 locations (Ajamopo, Lafogido, Igbo-Itapa, Ayegbaju, Ile-Lami compounds) were geographically close to one another and showing a cluster of cholera incidences. Also, 11(57.8%) locations (Ajamopo, Lafogido, Igbo-Itapa, Ayegbaju, Ile-Lami compounds, Ogbingbin, Ilare, Iredunmi, Olubuse, Moore and Sabo) were also proximal to waste dump site with markets. Furthermore, 3(15.8%) locations (Eleyele, Ajegunle, and Agric area) can be attributed to have a proximal link with wastes. Also, 1(5.3%) location (Sabo) was traced to abattoir (Table 4.3). Similarly, 4(21.1%) locations (Odi-Olowo, Mokuro, Seminary Opa and Mount Zion) were traced to be predominantly closed to rivers and waste dump site. All the historical cholera cases were found adjoining to roads and buildings (Table 4.4) (Figure 4.2).

Table 4.1: Proximity (300 meters buffer) from the ERFs to the Cholera Incidences

ERFs	Total no of ERF	Hot spots
Waste dump site	42	18
Market	18	7
Abattoir	34	2
Total	94	27

Table 4.2: Statistical Relationship between ERFs and Incidences of Cholera

ERF sites	Proximity to historic cholera cases	No proximity to historic cholera cases	Total	x^2	P-value
WDS	18(40.9)	26(59.1)	44		
Market	7(38.9)	11(61.1)	18	13.813	0.001*
Abattoir	2(5.6)	34(94.4)	36		
Total	27(27.6)	71(72.4)	98		

*Indicating significance

Table 4.3: Spatial Relationship between Cholera Incidences and Environmental Risk Factors through Geo-visualization.

ERFs	LOCATIONS
WDS (Market)	Ajamopo, Lafogido, Igbo-Itapa, Ayegbaju, Ile-Lami compounds, Ogbingbin, Ilare, Iredunmi, Olubuse, Moore and Sabo

Abattoir	Sabo
WDS	Eleyele, Ajegunle, and Agric area

Table 4.4: Spatial Relationship between Cholera Incidences and Vulnerable Elements through Geo-visualization.

River and WDS	Odi-olowo, Mokuro, Seminary Opa and Mount Zion
Road and buildings	Ajamopo, Lafogido, Igbo-Itapa, Ayegbaju, Ile-Lami compounds, Odi-Olowo, Mokuro, Seminary Opa, Sabo, Mount Zion, Ogbingbin, Eleyele, Iredunmi, Moore, Ajegunle, Illare, Olubuse and Agric Area.

WDS- Waste dump site

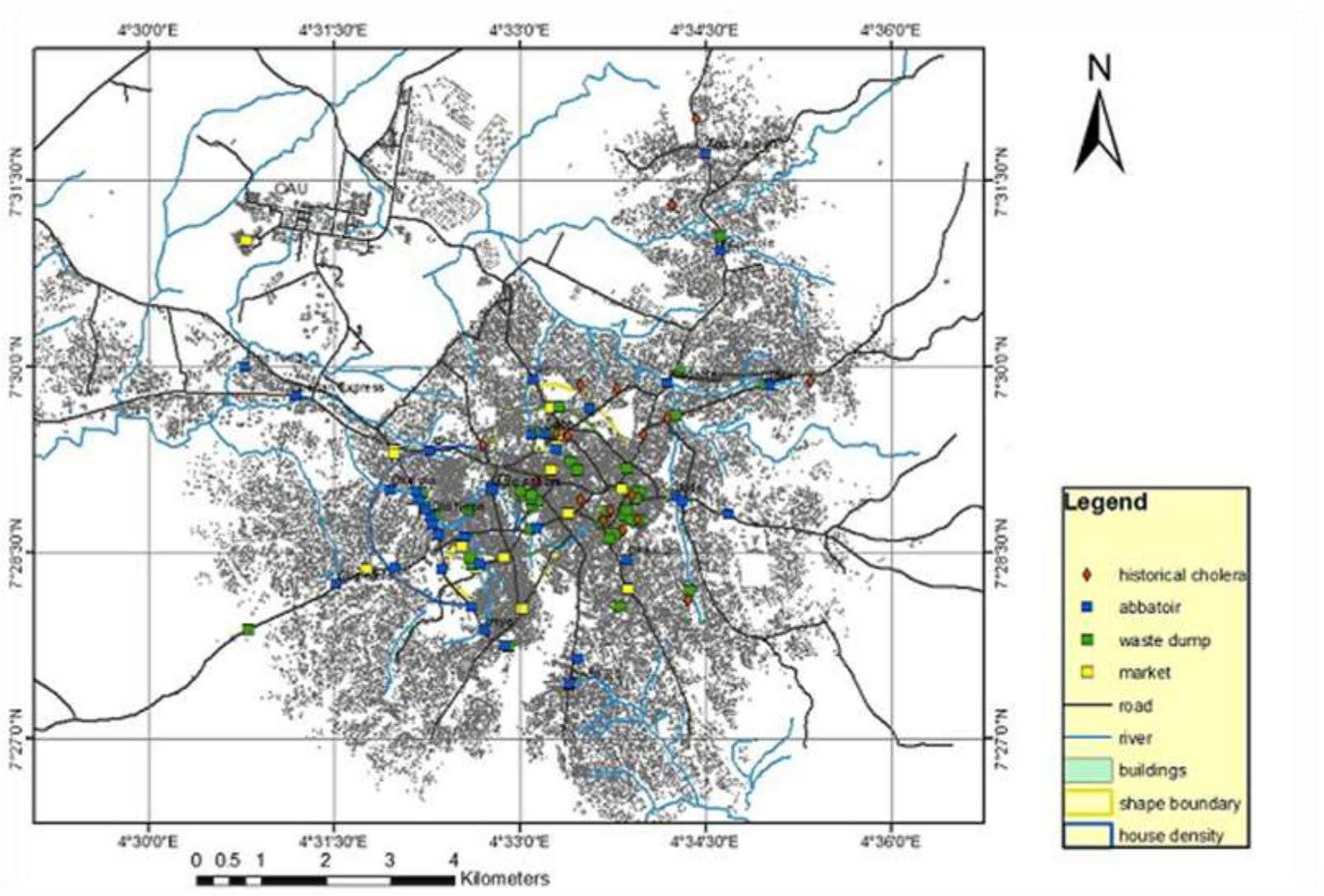


Figure 4.2: Spatial Relationship between Cholera Incidences and Environmental Risk Factors

4.3 Presence of *Vibrio cholerae* and Other Pathogenic Bacteria from the Water Sources in the Study Area

Fifty-five organisms were isolated from both well and stream water. Also, 7.3% *Vibrio cholerae* were isolated from stream and none from well (Figure 4.3). Other pathogenic bacteria isolated from the water sources were *Klebsiella pneumoniae* which had the highest percentage of 12.7% in well followed by *Enterobacter aerogenes* which had a frequency of 9.1% in well. *E. aerogenes* and *K. pneumoniae* were found at equal percentages 3.6% in stream. *Citrobacter koseri* and *Escherichia coli* had the same percentages of 7.3% in stream, while they had varying percentages of zero and 3.6% in well respectively. *C. freundii, K. aerogenes* and *Salmonella typhi* had the same percentages of 7.3% in well while they were found to be 1.8%, 5.5% and 3.6% respectively in the stream. *Pseudomonas aeruginosa* and *Shigella dysenteriae* occurred only three times in stream with 5.5% while they had varying percentages of 1.8% and 3.6% in stream. *Proteus mirabilis* had 3.6% in wells and none from stream (Figure 4.3).

4.4 Environmental Risk Map for the Study Area

Highest CFU count was found in the well and stream at Sabo community, Olanrewaju dump site and Iyana-Oja dump site. High CFU counts were found in Oduduwa Street, Ojoyin Street, and Famia Street. This is followed by Better life, Ola-Olu, Oduduwa slum, Olonode, Akaui Street, Lafogido, Igbo-Itapa and Ile-lami. Also, *Vibrio cholerae* was isolated in the stream at Iyana-oja, Famia road, Ojoyin and Olanrewaju Street. Hot spots clusters were seen mainly in areas of very high risk population. These areas are Iyana-Oja, Ajamopo, Ile-Lami, Oke-Atan, Igbo-Itapa, Sabo, Iyana-Oduduwa, Oja-titun, Old nepa, Oke-Ola, Ilode, Ojoyin, Aba-Iyagani, Opa, Kojumole, A.P and Eleyele (Figure 4.4).

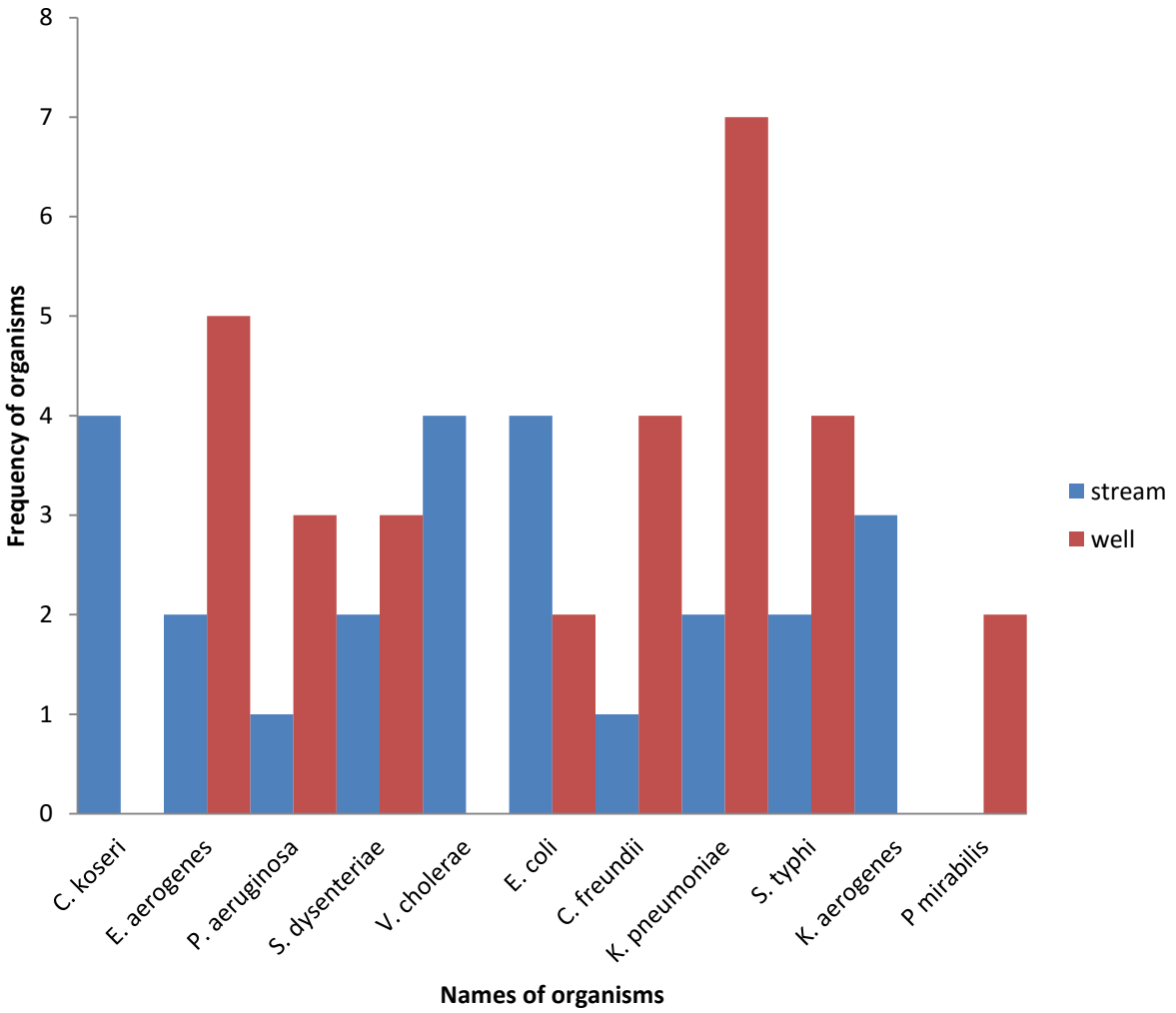


Figure 4.3: Frequency of Pathogenic Bacteria in Sampled Water Sources

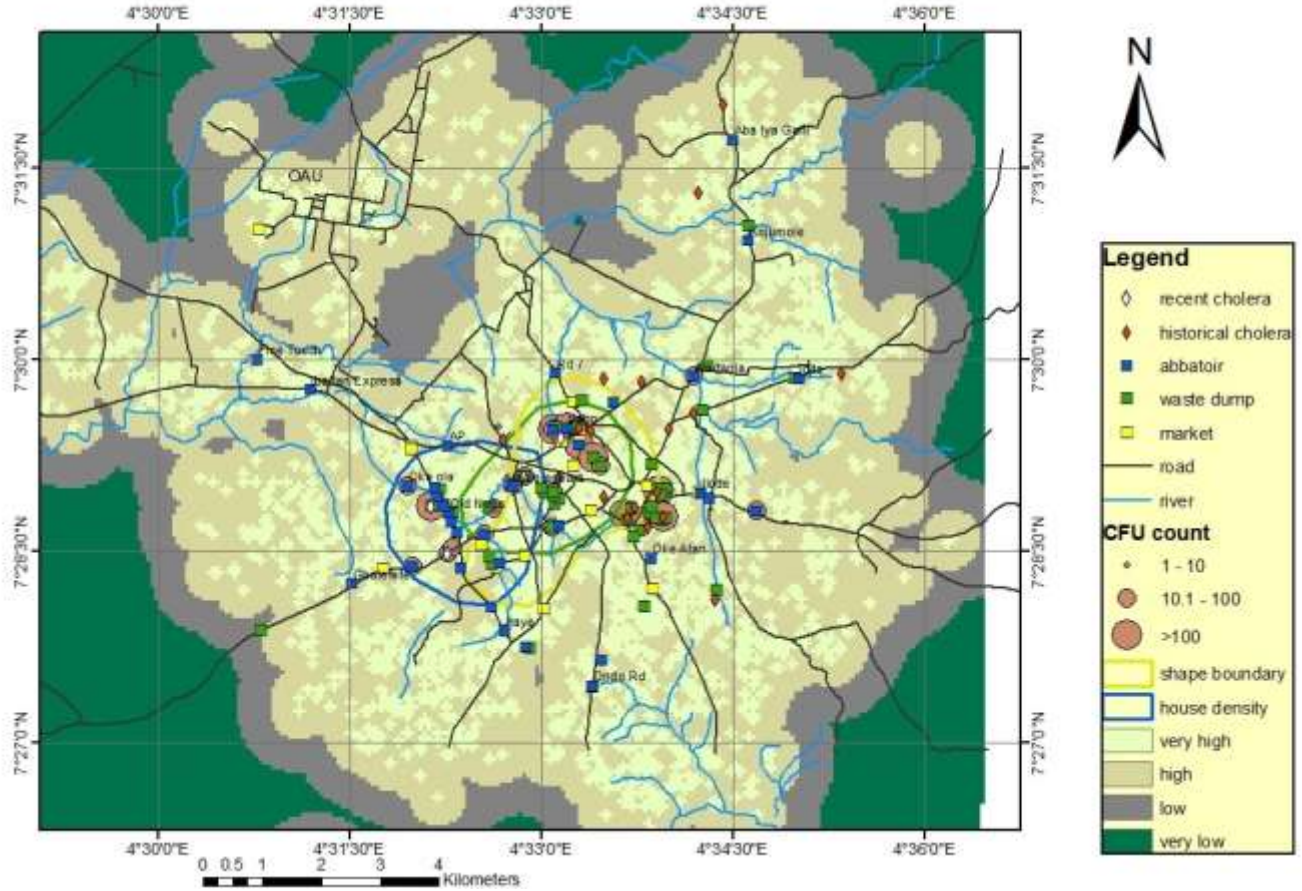


Figure 4.4: Environmental Risk Map for the Study Area

4.5 Socio-Demographic Characteristics of the Respondents

In Ife East Local government area, 63% of respondents were female compared to their male counterpart (37%). Also, 32.1% of the entire respondents interviewed were between the age group 20-29 and 30-39 while 11.1% were between 30-39 and 40-49 years old. In addition, 8.6% of the respondents were between 50-59years, the respondents who were 10-19 were the least in number and were found to be 4.9%. For the marital status, 27.2% was single, larger percentage (71.6%) of the respondents were married while 1.2% of the respondent was divorced. Furthermore, respondents with secondary education were the highest with 40.7% followed by primary education with 21%. Respondents with tertiary education were 19.5% while the least of the respondents were without education (18.5%). More than two-third 67.9% of respondents were from Ife East Local Government where the study was carried out. There was a significant difference among the socio-demographic characteristics of the respondents ($p < 0.05$) (Table 4.5).

Table 4.5: Socio-demographic Characteristics of the Respondents

Characteristics	Frequency	%	x^2	P-value
Gender				
Male	30	37	5.444	0.020*
Female	51	63		
Age group				
10-19	4	4.9		
20-29	26	32.1		
30-39	26	32.1	35.963	0.000*
40-49	9	11.1		
50-59	7	8.6		
60+	9	11.1		
Marital status				
Single	22	27.2		
Married	58	71.6	58.963	0.000*
Divorce 1	1.2			
Educational level				
None	15	18.5		
Primary 17	21	10.802	0.013*	

Secondary	33		40.7	
Tertiary	16	19.8		
Local Government Area				
Ife East	55	67.9	10.383	0.001*
Ife Central	26		32.1	

*Indicating significance

4.6 Environmental Hygiene Practice of the Respondents

Over one-third (35.8%) of the 81 respondents disposed their wastes into the rivers while less than one –quarter (23.5%) disposed their wastes inside drainages. Also, 21% of the respondents disposed their waste inside bush while 8.6% said that they disposed theirs inside the streams. In addition, 6.2% individuals reported disposing their wastes inside government vans and 4.9% used their backyard as a means for waste disposal. Furthermore, 27.2% of respondents interviewed claimed they were provided with refuse vans for waste collection while the remaining 72.8% claimed they were not provided with refuse vans. There was a significant difference between the methods of waste disposal used by the respondent ($p < 0.000$) (Table 4.6). A larger proportion of the respondents (82.7%) have their water supply for domestic activities and daily usage from well compared with 7.4% that are dependent on water from taps. Similarly, 3.7% stated that their source of daily water usage was from borehole while 3.7% used well

and stream. There was a significant difference between the sources of water used by the respondents at each location ($p < 0.000$) (Table 4.7).

Table 4.6: Waste Disposal Methods

Variable	Frequency	%	x^2	P-value
Waste disposal				
River	29	35.8		
Stream	7	8.6		
Bush	17	21	34.481	0.000*
Drainage	19	23.5		
Backyard	4	4.9		

Government -vehicle	5	6.2		
Refuse Vans				
Yes	22	27.2	16.901	0.000*
No	59	72.8		

*Indicating significance

Table 4.7: Source of Water Used by the Respondents at each Location

Source of water	Frequency	%	x^2	P-value

Well	67	82.7		
River	2	2.5		
Tap	6	7.4	195.875	0.000*
Bore-hole	3	3.7		
Well & River	3	3.7		

*Indicating significance

In the same vein, 61.7% of the people interviewed said that they treated their water recently while above one third 38.3% of the people interviewed claimed that they had never treated their water. Also, 9.9% of the respondents adhered to the fact that their water was treated three to four years ago when they had cholera outbreak, 6.2% responded that they treated their water a year ago, 18.5% treated their water within the last six months. Additionally, 17.3% and 16% of the respondents exclaimed that their source of water was last treated between two to three months and one month respectively. There was a significant difference between whether the respondents treated their water or not and the duration of the treatment ($p < 0.05$) (Table 4.8).

Thirty-seven (37%) of the respondents' wells were fully covered, 28.4% of the respondents reported that their wells were partially covered while 34.6% of them did not have a well cover. Also, less than half, 44.4% of the wells belonging to the respondents were protected with rings. About 23.5% of the respondents used plaster around the walls of their wells as measure of protection while 32.1% of them had nothing to protect the wall of their wells. There was no significant difference between the methods of well protection by the respondents in the study area ($p > 0.05$) (Table 4.9).

Table 4.8: Treatment of Water Used and Time of Last Treatment

Variable	Frequency	%	x^2	P-value
Water treatment				
Yes	50	61.7	4.570	0.033*
No	31	38.3		
Duration of treatment of well water				
Recently (≥1month)	13	16.0		
2-3 months ago	14	17.3		
Last 6 month	15	18.5	22.0	0.001*
A year ago	5	6.2		
Last 3-4 years	8	9.9		
Never	26	32.1		

*Indicating significance

Table 4.9: Covering of Well and Well Protection

Well covering	Frequency	%	x^2	P-value
Fully covered	30	37.0		
Partially-covered	23	28.4	0.709	0.702
No cover	28	34.6		
Means of well protection				
Rings	36	44.4		
Plaster	19	23.5	4.962	0.084
Nothing	26	32.1		

Among the people interviewed from the sites sampled, 37% used pit latrine while 24.7% used stream as their toilet. Additionally, 23.5% of the respondents used bush as hide-out for fecal disposal, 9.9% of the respondents used water closet system while 4.9% used river and bush. There was a significant difference between the toilet facilities used by the respondents in the study area ($p < 0.000$) (Table 4.10). Furthermore, 33.3% of the respondents had experienced flooding in their location while 66.7% reported that they had never experienced flooding in their location. Finally, 12.3% of the respondent exclaimed that they had experienced cholera outbreak before in their area. There was a significant difference

between flooding and cholera incidences in the study ($p < 0.0001$) (Table 4.11). Finally, 51.9% exclaimed that there was no environmental sanitation education conducted by anyone at their locations while 48.1% responded that there was an environmental sanitation education for them at their location. The statistical analysis showed that there was no significant difference between not giving the respondents at the study area environmental sanitation education and educating them ($p > 0.05$) (Table 12).

Table 4.10: Toilet Facilities Used by the Respondents

Toilet Facilities	Frequency	%	x^2	P-value
Pit latrine	30	37.0		

Stream	20	24.7		
Water closet	8	9.9	43.667	0.000*
Bush	19	23.5		
Stream and bush	4	4.9		

*Indicating significance

Table 4.11: Association between Occurrence of Flood and Incidences of Cholera Outbreaks

Occurrence of flooding	Incidence of cholera outbreak Yes	No	Total	P-value
Yes	10	17	27	0.0001*
No	0	54	54	
Total	10(12.3)	71(87.7)	81	

*Indicating significance

Table 4.12: Environmental Sanitation Education for the Respondents at the Locations

Environmental sanitation education	Frequency	%	x^2	P-value
Yes	39	48.1	0.50	0.823
No	42	51.9		

4.7 Environmental Hygiene Practices at Locations

Wastes from Iso-Obi, Oja-tuntun and Sabo were being deposited inside a stream near the market. The stream flows through Oduduwa Street (where an abattoir is located), the rear of Oja-tuntun, Iyana-oja and through Ola-olu Street. It was observed that the places where this stream flowed through were residential areas and places where different activities like buying and selling of different things like food stuffs, perishable and non- perishable goods are performed. Slaughtering of animals for meat production and cooking of food for the purpose of selling to human beings for consumption were carried out at these locations. It was also observed that most of the people residing near this stream defecate inside it and the workers at this slaughter slabs did not consider constructing a toilet as a priority, therefore using the stream as hide outs for their unhygienic practices. Different waste products such as used

papers, rags, baskets, cartons, food remnants, decaying leaves, fruits and vegetables could be seen from this waste dump site. The areas surrounding the dump site are highly urbanized and residential buildings are beside this dump site (Plate 4.1). The second plate (Plate 4.2) presented in this study was taken at the rear of a house at Ile-Lami compound. It is the site for the deposition of wastes and also a site that serves as a toilet for open defecation. The drainage runs through many compounds, linking Ajamopo, Lafogido and Ile-lami. The common method for the deposition of all forms of wastes at this compound was disposal inside drainage and bushes. This is evident from this picture because it is just an example of the common practices at the compounds (Plate 4.2).

Plate 4.1: Waste Dump Site at Iyana-Oja

Plate 4.2: Waste Dump Site and the Open Defecation Site at Ile-Lami Compound

The bridge at Ola-Olu Street, where a stream flows through, is a location for the deposition of wastes by the people at this community. Close to the bridge, an abattoir was located, residential buildings, and different shops were also cited. Most of the abattoir workers and shop owners didn't have access to toilets, which was responsible for their making use of the stream as their toilet. Therefore, when rain falls, wastes were being carried from the bridge to the main road (Plate 4.3). These wastes constitute different nuisances for road users and also for the workers around the place. Abattoir workers complained that water flows into their well during raining season, and on viewing the well, it had no cover, no plastering or ring inside. This was viewed as a sure way for outbreak of diseases.

An uncovered shallow well with no inner protection was located at Lafogido compound (Plate 4.4). The households interviewed agreed to the fact that they use the water for different activities and they also drink from it. This well had been in existence for more than 20 years.

Plate 4.3: Wastes Overflowing from the River to the Main Road during the Raining Season at Ola-Olu Street

Plate 4.4: A Typical Example of a Well at Lafogido Compound.

CHAPTER FIVE

DISCUSSION

This study showed that proximity to waste dump sites and market were identified as the major factor associated with the previous cholera cases in Ile-Ife while the least was abattoir. It was also identified that a minimum distance of 300 metres of waste dump sites, markets and abattoirs to the residential buildings (cholera incidences) can predispose inhabitants within the areas to cholera ($p < 0.001$). This finding is consistent with a study carried out by Osei and Duker (2008) that the optimum spatial discrimination of cholera occurs at 500metres away from refuse dump. In addition, according to the Standard Abattoir Act (1988), it was stated that abattoir should not be located close to dwellings, schools, churches and other public or commercial buildings.

For waste dump sites, majority of the cholera cases were found proximal to waste dump site. Therefore, it was concluded that proximity of residents to waste sites would predispose them to cholera. Also, a research undertaken by Osei *et al.*, (2010) in Kumasi, Ghana on the spatial dependency of *V. cholera*e on open space refuse dumps with a spatial statistical modeling suggests that cholera risk is relatively high when inhabitants live in close proximity to waste dumps and where there are numerous refuse dumps. Similarly, the cholera outbreak at these places might be due to the high rate of breeding of flies which could serve as a carrier of *V. cholerae* from the waste dump sites polluted by excreta and human garbage to man's food and water. Osei and Duker (2008) also identified the occurrence of flies in waste

dump sites. Research has also proven that the common housefly (*Musca domestica*) and flies generally are mechanical vectors of many kinds of pathogens such as bacteria, protozoa, viruses, and helminth eggs (Levine and Levine, 1990). Fotedar (2001) undertook a study on vector potential houseflies (*Musca domestica*) in a transmission of *V. cholerae* in India and this study ascertained the vector potential of the domestic housefly as a carrier of *V. cholerae* in Delhi, India, where an outbreak of cholera was encountered.

Flooding could occur during the heavy out pour of rain, thereby causing contaminated water to flow into the water sources used for human daily activities. Also, surface run-offs from these dumps sites could serve as a major pathway for fecal and bacterial contamination of rivers and streams. Meanwhile, it was also noted from this study that there was a significant difference between flooding and cholera incidences ($p < 0.001$). Violeta, (2007) also conducted a study on the influence of environmental factors on the presence of *V. cholerae* in the marine environment and it was stated that run-offs also carry high organic loads, leading to stagnation and increased salinity of rivers and streams, thus creating suitable environmental niches for the cholera *Vibrio*. Due to bad toilet habits of most of the respondents interviewed in this area, the refuse dumps contained high fecal matter among which might have been from a *V. cholerae* carrier. Surface drainage from such refuse dumps will wash into water sources which, when used by humans, enhance the transmission of the cholera pathogen.

Furthermore, there was an association between market and cholera cases in the study areas because market is associated with bulk of wastes and these wastes are being deposited inside the nearby streams and wells in the markets. The markets which were found to be close to waste dump sites were mostly located in the North-eastern part of the study area. These markets were associated with high density population because a lot of buildings were cited

from the map. Some of the markets surveyed were also found to be proximal to water bodies which always serve as dumping sites. The market women interviewed claimed that they were not provided with refuse vans for the collection of their wastes and due to the numerous amounts of wastes generated, this made them engage in dumping into the streams and rivers near them. Therefore, the presence of markets obviously affects the positioning or distribution of major wastes in the study area.

More so, market sites were found running parallel to major transportation routes as the sites were characterized with a lot of road networks which made them generally a center of commerce. Also, markets are known to be close to residential areas for easy accessibility. Oja-tutun market in the study area is the largest market in Ile-Ife and a major center of commerce which lacked adequate sanitation measures especially in the deposition of waste. Due to lack of appropriate waste collection systems in this place, people found it convenient to deposit their waste inside the stream close to the market. Cholera outbreaks could have occurred due to the fact that micro-organisms found their way to the various waste dump sites around the market. During wet seasons, water could percolate through the soil, carrying these organisms to local surface water, ground water or sea as shown in the study carried out by Irene (1996). Therefore, proximity to the market plays a significant role in cholera outbreak because of the large amount of wastes generated.

Specifically, the major outbreak of cholera in Ile-Ife which was found to occur at Sabo could be further associated with the presence of abattoir in this community. Ideally, abattoirs should be located where there would be ample supply of water for cleansing and a means of transporting the treated remnants. However, for Sabo community, the abattoir is located inside the community which made the wastes from this activity to be poorly handled, hence

serving as a breeding place for flies which could predispose them to various diseases especially cholera. Also, other environmental factors like markets and waste dump sites were found near this community. This cluster of factors could further enhance the spread once there is an outbreak.

For the vulnerable element, it was deduced that there was an inter-link between cholera prevalence and proximity to water bodies. This is because water bodies are generally being polluted by refuses and human excreta due to the indiscriminate defecation practices of inhabitants inside water bodies. The risk of cholera incidence is assumed to be greater for people who live closer to them and thus, will possibly tend to have higher cholera prevalence than those who live farther. Ali *et al.* (2002) corroborates the findings of this study from their research in Bangladesh on identifying environmental risk factors of cholera in endemic area with a raster GIS approach which reveals cholera infection is enhanced by proximity to potentially polluted surface water bodies. Thus, this is also an indication that the effects of dump sites on cholera infection require surface water as an intermediate pathway. Therefore, any attempt to prevent defecation at dump sites will reduce fecal contamination of rivers and streams. This will in turn reduce cholera infection during any outbreak. Also, the epidemiological work of John Snow in London revealed the association between cholera and contaminated water even before any bacterial were known to exist (Snow, 1855). Odi-Olowo, Mokuro, Seminary Opa, Mount Zion, and Olubuse from the South-western part of the study area were areas which are positioned near water bodies, and thus the cholera cases in these communities maybe attributed to proximity to water bodies.

In the same vein, the waste dump sites observed in the study were found to be clustered around the roadside and mainly in the North-eastern part of the study area

especially around Ojoyin Street, Lafogido, Igbo-Itapa, Ajamopo, and Ile-Lami compounds. These areas were characterized with a lot of buildings which signify development. This development can contribute to overcrowding causing the easy spread of diseases. These wastes constituted nuisances to the environment and formed the major breeding site for rodents and other disease causing organisms in the area. Poverty and ineffective provision of adequate waste disposal methods can contribute greatly to the indiscriminate disposal practices engaged in by the indigenous people. Meanwhile, government policies or institutions responsible for community health are usually underfunded or not motivated to control the situation. Doan (1998), UNEP (2002), and Ashbolt (2004) identified that the occurrence is rampant in many developing countries. A study carried out in the Eastern area of Nigeria on proximity of municipal waste and rate of hospitalization for malaria by Edmund and Raphael (2008) indicated that proximity of waste dump to roads and residential areas has imparted negativity on the health of the public.

V. cholerae was isolated only from stream in the study area and this is due to the fact that streams are more contaminated with different kinds of wastes than well. This finding is similar to the report of Akoachere and Christelle (2014). *K. pneumoniae* was the highest occurring organism in the water source from well with the percentage appearance of 12.7%. *K. pneumoniae* found its way into the well as a result of poor sanitation of people in the location. *K. pneumoniae* can cause pneumonia, urinary tract infections. *C. koseri* is a free living organism in the soil. However, it can also become pathogenic when it gets to human body, causing meningitis according to Babyn (2011). *E. coli*, *S. typhi*, and *S. dysenteriae* were isolated from the water sources and that connotes fecal contamination of water sources. Pegram *et al.,* (1998) states that the presence of *S. dysenteriae* indicates recent human fecal pollution because the organism is not particularly stable in water environments. Melo *et al.,* (1997)

isolated these organisms from water bodies heavily contaminated with fecal material in their research on coliform and *Salmonella* in seawater near domestic sewage sources in Fortaleza ceara, Brazil. According to Craun *et al.,* (1971) and CDC, (2009), it was stated that the presence of these organisms does not only make the water unsuitable for human consumption, but poses serious health concerns. Similar study by Adejuwon and Adelakun (2012) reported the presence of these bacteria in drinking water sources near similar environmental risk factors in their research on physio-chemical and bacteriological analysis of surface water in Ewekoro Local Government Areas in Ogun state in a case study of Lala, Yobo and Agodo rivers.

The environmental risk map produced from this study serves as a prediction to the future outbreak of pathogenic diseases. The high level of contamination of the water sources is due to the presence of pathogenic bacteria and higher colony forming unit (CFU) counts present in them. The reason for the high CFU concentration in Sabo community is because there is a cluster of abattoirs, waste dump sites and markets around the location. The combination of the three environmental risk factors in the same region further aggravate the situation and make the areas to be more vulnerable to cholera infection and other bacteria diseases caused by poor sanitation. Other locations with higher CFU counts were Ola-oluwa, Iyana-Oduduwa, Ojoyin, Olanrewaju, Isale-Agbara, Famia, Better-life, Akaui, Oja titun, Iyana Oja, Olorunsogo, Olonode, Lafogido, Igbo-Itapa, and Ile-lami compounds with or without history of cholera incidences. These areas could be predisposed to outbreak of diseases because they exceeded the WHO permissible limits for drinking water (WHO, 1996, 1997; EPA, 2002). The work of Obiri-Danso *et al.,* (2005) on the spatial dependency of cholera prevalence on potential cholera reservoirs in an urban area in Kumasi, Ghana deduced that the spatial distribution of cholera prevalence is dependent on higher bacterial counts found in water. This signifies that areas with the highest CFU counts are at higher risk of outbreak of diseases. It was

also observed from the study that the new detected cases of *V. cholerae* are spreading towards the North-western part of the study area. These areas are Famia Road, Olanrewaju street and Ojoyin community and the last one at the North-eastern part of the study area (Iyana-Oja market), in proximal to where cholera outbreak had occurred before. This poses a serious risk to the inhabitants of these communities because any contact with the water source could lead to an outbreak of cholera and other pathogenic diseases. Furthermore, the designated risks zones from very high, high, medium to low simply implies that locations that are within the very high to high risk spots are at greater risk of contracting diseases than the medium risk areas, while the least to be predisposed to diseases are locations at the low risk zones. Similarly, cholera hot spots clusters were seen mainly in areas of very high to high risk population. These areas are Iyana-Oja, Ajamopo, Ile-Lami, Oke-Atan, Igbo-Itapa, Sabo, Iyana-Oduduwa, Oja-titun, Old-nepa, Oke-ola, Ilode, Ojoyin, Aba-Iya Gani, Opa, Kojumole, A.P, and Eleyele. If proper interventions are not taken, this proximity of residential buildings to disease hot spots could play an important role in transmission of the disease to human.

From the result of the questionnaire analysis, the socio-demographic characteristics of the respondents were found to be associated with their environmental sanitation practices. Basically, females and married were observed to have poor environmental sanitation practices compared to male, likewise, the single's and divorced were also found to have poor environmental sanitation practices. Also, age group of 20 -29 and 30 - 39 had poor environmental sanitation practices while respondents with secondary school education also had poor sanitation practices. Ife east Local Government Areas were observed to have poor environmental sanitation compared to Ife Central because majorities of the environmental risk factors were located there. Furthermore, larger percentages of the respondents in the locations where water was sampled, with or without historical cholera cases were areas with

poor environmental sanitation. They lacked access to quality water, good toilet facilities, and acceptable waste disposal methods. This was because majority of the respondents used rivers and drainages as the method of their waste disposal. Also, majority of the respondents were also not provided with refuse vans for their waste collection. Meanwhile, it has been reportedly said that these areas with inadequate basic and essential amenities are inevitably prone to cholera and other pathogenic diseases (Ackers *et al*., 1998; Huq *et al*., 2003; Borroto and Martinez-Piedra, 2000). Also, there was a significant difference among the responses of the respondents as regard where they sourced their water from, water treatment and the duration of the treatment ($p < 0.005$). Above eighty percentage (88.9%) of the respondent sourced their water for daily use from well, some from rivers while more than half use untreated water. Therefore, the risk of cholera infection is also high when majority of the people drink from rivers, streams, ponds and untreated water (Osei *et al.,* 2010). Similar studies on contributing factors to cholera in Zimbabwe by Anderson (2009) revealed that untreated surface water for household use is a source of re-occurrence of cholera outbreak in various parts of the world.

Pit latrines can facilitate fecal contamination of water sources especially those that are unprotected. Meanwhile, above one-third (37%) of the respondents used pit-latrines which they poorly handled because there were many households in a community sharing one toilet and which may compromise the hygiene, thereby leading to the outbreak of diseases. In addition, 24.7% used stream while 23.5% made use of bush as their toilet. In the rainy season, as the different sites for defecation get flooded with the rain water, fecal matter can easily contaminate the water sources. More so, some of these wells were without covering and can easily become contaminated by run offs from open toilets and waste dump sites. Although, the protection of wells were not statistically significant in the study, but cholera and other bacterial diseases are possible effects of drinking water from such wells. This finding is in agreement

with the study conducted in Uganda by Sa'eed and Mahmoud (2014) on factors contributing to the re-occurrence of cholera. It was reported that epidemics of a disease can occur when toilet facilities are not adequate.

Furthermore, most of the locations where the water samples were gotten in this study were slums and old squatter settlements. Igbo-Itapa, Lafogido, Ajamopo, Ayegbaju, and Ile-lami are indigenous areas in Ile-Ife and are geographically close to one another. This could be the reason for the clustered outbreak around these compounds. Smallman-Raynor and Cliff, (1998); Trevelyan *et al.,* (2005) and Pyle, (2010) corroborated this finding by concluding that it is likely for the disease to spread from its origin to proximal communities earlier than communities which are farther away. Sabo community, Ogbingbin, Iredunmi, Ola-olu, Moore, and Ilare streets where cholera had occurred before are characterized as a typical example of a slum. Sur *et al*. (2005) in a research conducted on the severe cholera outbreak following floods in a Northern district of west Bengal, India identified slum and squatter environments to increase the risk of cholera.

Furthermore, some of the respondent (33.3%) agreed that they always experience flooding and this could enhance the spread of bacteria. The cholera outbreak data used for the study occurred in the months of August, September and October, 2010 and 2011. This affirms that the outbreak occurred during raining season. Also, flooding was significantly associated with cholera outbreaks ($p < 0.0001$) in this study. A study conducted by Borroto and Martinez-Predia (2000) in Mexico on the geographical patterns of cholera, they stated that flooding makes inhabitants to be predisposed to diseases because unfavorable topography, soil, and hydro-geological conditions make it difficult to attain and maintain high sanitation standards among inhabitants living in these territories. In conclusion, environmental sanitation education

was not statistically significant in the study (P > 0.05), this signifies that giving environmental sanitation education does not have anything to do with the outbreak of diseases but rather the provision of the essential facilities that will make the inhabitants to embrace good environmental sanitation practices and neglect bad environmental sanitation practices.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study revealed that waste dump sites and markets had the highest predisposing attributes to the outbreak of cholera while the least was abattoir. In this study, *Vibrio cholerae* was detected in Ojoyin, Iyana-Oja, Olanrewaju and Famia Road. Meanwhile, one of the locations (Iyana-Oja) where *V. cholerae* was detected was an area close to the last cholera epidemic (Sabo) location. The spatial relationship between cholera incidences and ERFs generated in this study showed that areas with historical cholera cases were close to waste dump sites near market, rivers/streams and abattoirs. In the same vein, proximity analysis performed showed the locations that are within a distance of 300 metres from the cholera cases to the environmental risk factors. These locations were identified as areas that are at higher risk of being predisposed to cholera and other pathogenic diseases. The questionnaires analysis revealed that the environmental hygiene practice of inhabitants at the study area was very poor due to poor waste management techniques and poor water quality. Environmental risk map indicated the very high, high, low and very low risk areas to cholera incidences and also

indicated the areas with high CFU count (Sabo, Ola-oluwa, Iyana-Oduduwa, Ojoyin, Olanrewaju, Isale-Agbara, Famia, Better-life, Akaui, Oja titun, Iyana Oja, Olorunsogo, Olonode, Lafogido, Igbo-Itapa and Ile-lami compounds), medium CFU count and low CFU count.

6.2 Recommendations

Communities such as Ajamopo, Igbo-Itapa, Ile-lami, Ayegbaju, Ojoyin, Sabo, Ola-Olu, and Iyana Oduduwa which have waste dump sites proximate to them should be given quick intervention by removing the wastes and providing refuse vans to eliminate such nuisances. Also, communities that are proximal to markets should be properly observed because of the huge amount of wastes markets generate. Also, indiscriminate dumping of wastes should be highly prohibited and anybody that dumps wastes indiscriminately should be sanctioned by health authorizes in the region.

Furthermore, communities such as Seminary Opa, Mokuro, Odi-Olowo, Sabo and Mount Zion that have rivers and streams close to them should be properly monitored more importantly by creating good drainages for the free-flow of water in order to control them from over-flowing to residential buildings which could cause flooding and leads to outbreak of diseases. Also, Sabo community that has an abattoir in her community should be banned from operating by appropriate health authorities in the region.

In the same vein, government should make it mandatory for each house to have a good toilet facility which will prevent inhabitants from disposing their excreta into streams and bushes because this act could contaminate the water, especially when rain falls and the run-offs percolate into the soil thereby contaminating the underground water and which could lead to a

favorable environment for *Vibrio* species to survive. Also, government should make sure that markets and abattoirs are sited at least 300 metres away from residential areas.

It is also recommended that water sources in communities such as Sabo, Ola-oluwa, Iyana-Oduduwa, Ojoyin, Olanrewaju, Isale-Agbara, Famia, Better-life, Akaui, Oja-titun, Iyana Oja, Olorunsogo, Olonode, Lafogido, Igbo-Itapa and Ile-lami compounds with higher CFU counts should be treated. Communities such as Ojoyin, Iyana-Oduduwa, Famia and Olanrewaju with their water sources being contaminated with the presence of *V. cholerae* should be properly monitored to prevent outbreak of diseases. Also, periodic water testing should be undertaken by health authorizes in the regions every three months to detect any micro-organisms that may be present in order to apply treatment accordingly.

Crowing it all, communities being categorized as very high and high risks areas such as Iyana-Oja, Ajamopo, Ile-Lami, Oke-Atan, Igbo-Itapa, Sabo, Iyana-Oduduwa, Oja-titun, Old-nepa, Oke-ola, Ilode, Ojoyin, Aba-Iya Gani, Opa, Kojumole, A.P, and Eleyele should be provided with essential facilities to promote their environmental hygiene practices in order to prevent outbreak of pathogenic diseases amidst them and for them to always embrace good environmental sanitation practices.

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APPENDIX I: Coordinate of Abattoirs in the Study Areas with the Designated Zones

S/n	Latitude	Longitude	Name	Zone
1.	07.515553	004.576987	Kojumole Abattoir	8
2.	07.528715	004.575035	Aba Iya Gani Abattoir	8
3.	07.494385	004.559412	Iyana Oduduwa Abattoir	2
4.	07.498233	004.551922	Road 7 Abattoir	2
5.	07.49777	004.569875	Aladanla Abattoir	8
6.	07.497548	004.58366	Idita Abattoir	2
7.	07.482562	004.570842	Ilode Abattoir	2
8.	07.480187	004.57815	Kosere Abattoir	8
9.	07.481887	004.571932	Oke ogbo Abattoir	8
10.	07.474105	004.564353	Oke Atan Abattoir	8
11.	07.460775	004.557898	Olurin Ondo Rd Abattoir	1
12.	07.457337	004.556705	Ondo Road Abattoir	1
13.	07.496075	004.519847	Ibadan Express Rd Abattoir	8

14.	07.500003	004.512935	Fine Torch Abattoir	8
15.	07.488713	004.537723	A.P Abattoir	1
16.	07.490955	004.551515	Ola Olu Abattoir	5
17.	07.470768	004.525265	Gbalefefe Abattior	1
18.	07.472893	004.533207	Ola jesu, oke otubu Abattior	1

S/n	Latitude	Longitude	Name	Zone
19.	07.47288	004.53945	Al-wud Abattior olorunsogo	1
20.	07.467647	004.543492	His grace Abattior Islamic rd	1
21.	07.464588	004.545193	Ile aanu Abattior Iraye	1
22.	07.462488	004.547987	Olorunwa iraye rd	8
23.	07.473437	004.544652	Better life Abattior	4
24.	07.47721	004.542568	Adura Abattior olorunsogo	3
25.	07.483897	004.546158	Monyashiu Abattior Isale Agbara	6
26.	07.483435	004.546253	Isale agbara Abattior 2	6
27.	07.479893	004.537913	Old nepa Abattior	1
28.	07.480797	004.537298	Olajesu Abattior Olanrewaju	1
29.	07.483447	004.532535	Oke ola Abattior	1
30.	07.483253	004.536013	Ola sheu Abattior	1

31.	07.482113	004.536458	Ope oluwa Abattior	1
32.	07.47885	004.538268	His mercy Abattior	1
33.	07.477373	004.538973	Ondo rd Abattior	1
34.	07.491077	004.553323	Sabo Abattoir	5
35.	07.488942	004.554903	Oduduwa Strt Abattoir	5
36.	07.47838	004.552343	Ita Agbon Abattoir	5

APPENDIX II: Coordinate of Waste Dump Site in the Study Areas with the Designated Zones

S/n	Latitude	Longitude	Name	Zone
1.	07.517517	004.577092	Gbalefefe Dump site	1
2.	07.494668	004.555188	Apollo Dump Site	2
3.	07.499173	004.571698	Aladanla Waste Dump	8
4.	07.486193	004.564363	oja Ife Waste Dump	2
5.	07.483205	004.56623	Ijio Waste Dump/Slum	2
6.	07.467713	004.563472	Back of Moremi Waste Site	8
7.	07.457282	004.556637	Ondo Road Waste Dump	1
8.	07.491162	004.551887	Ola Olu Waste Dump Site	5

9.	07.48724	004.55686	Oduduwa Strt Refuse Dump/slum	5
10.	07.486075	004.557642	Akaui Street Refuse Dump	2
11.	07.464582	004.513362	Ile isinku	1
12.	07.462355	004.548477	Iraye dumping site	8
13.	07.473215	004.543488	Better life 1 dumping site	4
14.	07.474218	004.543122	Better life 2 dumping site	4
15.	07.480055	004.538393	old nepa dumping site	1
16.	07.480852	004.5356	Olanrewaju 1 dumping site	1
17.	07.483048	004.536722	CAC dumping site	1
18.	07.480948	004.53711	Olanrewaju dumping site	1

S/n	Latitude	Longitude	Name	Zone
19.	07.491007	004.554393	Sabo Waste Dump Site1	5
20.	07.490955	004.554085	Sabo Waste Dump Site2	5
21.	07.491267	004.554698	Sabo Waste Dump Site3	5
22.	07.478107	004.551403	Ita Agbon Waste Dump	5
23.	07.482713	004.550278	Ojoyin Waste Dump Site1	5
24.	07.482538	004.550602	ojoyin Waste Dump Site2	5
25.	07.48118	004.551637	Ojoyin Waste Dump Site3	5
26.	07.48178	004.552262	Orita Fogo Waste Dump Site	5
27.	07.4822	004.551472	Ojoyin Waste Dump Site4	5

28.	07.482662	004.551487	Ojoyin Waste Dump Site5	5
29.	07.483238	004.54998	ojoyin WDS/Gutter	6
30.	07.48478	004.547877	Ojoyin WDS/Bridge	6
31.	07.480517	004.561773	Igbo-Itapa WDS	2
32.	07.479965	004.564053	Ajamopo/Ilode WDS	2
33.	07.469813	004.572867	Odi-olowo Strt WDS	2
34.	07.493383	004.570993	Esinmirin WDS	2
35.	07.480663	004.542992	Alapata WDS	2
36.	07.483213	004.56518	Ayegbaju WDS	2

S/n	Latitude	Longitude	Name	Zone
37	07.482292	004.565605	Ayegbaju WDS2	2
38	0 7.480697	004.56442	Ilode bridge WDS	2
39	07.478935	004.5658	Ajamopo WDS	2
40	07.479237	004.566165	Ilelami cmpd WDS	2
41	07.47934	004.564933	Ilelami/OkeAtanWDS	2
42	07.47755	004.562752	Ayetoro/Iloro strtWDS	2
43	07.476777	004.561993	Otutu WDS	2

44	07.479063	004.561065	Ajamopo WDS	2

APPENDIX III: Coordinate of the Markets at the Study Areas with the Designated Zones

S/n	Lat (^{0}N)	Long (^{0}E)	Name	Zone

1.	07.494408	004.554172	Apollo Market	2
2.	07.483472	004.563795	Oja Ife Market	2
3.	07.48267	004.570522	Ilode Market/dump site	2
4.	07.470057	004.564515	Iloro Market	8
5.	07.516923	004.513075	OAU Central Market	8
6.	07.48919	004.552552	Oja Tutun Market Front	5
7.	07.486062	004.554108	Oja Tutun Market Iremo	5
8.	07.488702	004.533068	Mayfair Market	8
9.	07.480192	004.556423	Itakogun Market	5
10.	07.490722	004.554933	Iso Obi/Sabo Market	5
11.	07.472688	004.529288	Gbalefefe market	8
12.	07.488333	004.532995	Urbanday market	8
13.	07.474433	004.547843	Itamerin market	4
14.	07.475767	004.542045	Olorunsogo market	4
15.	07.467397	004.550288	Bosa market	8
16.	07.472883	004.544115	Betterlife market	4
17.	07.489353	004.554967	Oduduwa Strt Market	2
18.	07.497465	004.5831	Idita Market	2

APPENDIX IV: Coordinate of the Sampling Points with the Water Source and the

Designated Zones of the Environmental Risk Factors

S/n	Locations	Lat (^{0}N)	Long (^{0}E)	Source	ERF	Zone
1	A.P Abattoir	07.488713	004.537723	Stream	Abattoir	1
2	Oke-Ola Abattoir	07.483447	004.532535	Stream	Abattoir	1
3	Ola Shehu Abattoir	07.483253	004.536013	Well	Abattoir	1
4	Ope Oluwa Abattoir	07.482113	004.536453	Well	Abattoir	1
5	Olanrewaju Dump	07.480852	004.5356	Stream	Abattoir	1
6	Ola Jesu Oke Otubu	07.472893	004.533207	Stream	Abattoir	1
7	Al-Wud Olorunsogo	07.47288	004.53945	Well	Abattoir	1
8	Ondo Road Abattoir	07.477373	004.538973	Well	Abattoir	1
9	Old Nepa Abattoir	07.479893	004.537913	Stream	Abattoir	1
10	Famia Rd Dump Site	07.474668	004.5378	Stream	Abattoir	1
11	Apollo Dumpsite	07.494668	004.555188	Well	Market	2
12	Iyana Oduduwa Abb	07.494385	004.5591412	Stream	Market	2
13	Oja Ife Waste Dump	07.486193	004.564363	Well	Market	2
14	Oja Ife Market	07.483472	4.563795	Well	Market	2
15	Adura Olorunsogo	07.47721	004,542568	Stream	Abt&WDS	3

16	Olorunsogo	07.476767	004.540657	Stream	Abt&WDS	3
17	Olorunsogo	07.476983	004.54144	Well	Abt&WDS	3

S/n	Locations	Lat (^{0} N)	Long (^{0} E)	Source	ERF	Zone
18	Olorunsogo	07.475393	004.538403	Well	Abt&WDS	3
19	Olorunsogo Market	07.475767	004.542045	Well	Abt& Mkt	4
20	Better Life Abattoir	07.473437	004.544652	Stream	Abt& Mkt	4
21	Better Life Market	07.472883	004.544115	Well	Abt& Mkt	4
22	Ola-Olu Well	07.490955	004.551515	Stream	WDS&Mkt	5
23	Ola-Olu Abattoir	07.490908	004.55148	Stream	WDS&Mkt	5
24	Sabo WDS	07.491267	004.554422	Well	WDS&Mkt	5
25	Sabo Wds2	07.49112	004.554422	Well	WDS&Mkt	5
26	Sabo Abattoir	07.491077	004.553323	Well	WDS&Mkt	5
27	Oduduwa Strt Abat	07.488942	004.554903	Stream	WDS&Mkt	5
28	Oduduwa WDS/Slum	07.48724	004.55686	Well	WDS&Mkt	5

29	Akaui Strrt Rds	07.486075	004.557642	Well	WDS&Mkt	5
30	Oja Titun Market	07.48919	004.552552	Well	WDS&Mkt	5
31	Iyana Oja WDS	07.489847	004.552677	Stream	WDS&Mkt	5
32	Ojoyin WDS	07.482662	004.551487	Well	WDS&Mkt	5
33	Orita Fogo WDS	07.48178	004.552262	Well	WDS&Mkt	5

S/n	Locations	Lat (^{0} N)	Long (^{0} E)	Source	ERF	Zone
34	Itakogun Market	07.480192	004.556423	Well	WDS&Mkt	5
35	Ita Agbon Abat	07.47838	004.552343	Well	WDS&Mkt	5
36	Ojoyin WDS	07.48478	004.547877	Stream	WAM	6
37	Isale-Agbara Abat	07.483435	004.546253	Stream	WAM	6
38	Monyashiu Abat	07.483897	004.546158	Well	WAM	6
39	Olonade Street	07.480572	004.543822	Well	WAM	6
40	Isale Agbara Street	07.483987	004.546392	Stream	WAM	6

41	Apata Street	07.4804	004.544367	Stream	WAM	6
42	Ibadan Exp Rd	07.496075	004.519847	Stream	Ctrl	8
43	Aladanla Abattoir	07.49777	004.569875	Stream	Ctrl	8
44	Iloro Market	07.470057	004.564515	Stream	Ctrl	8
45	Bosa Market	07.467397	004.550288	Well	Ctrl	8
46	Mayfair Market	07.488702	004.533068	Well	Ctrl	8
47	Oke-Atan Market	07.474105	004.564353	Stream	Ctrl	8
48	Kosere Abattoir	07.480187	004.57815	Stream	Ctrl	8
49	Iraye Dumpsite	07.462355	004.548477	Well	Ctrl	8

S/n	**Locations**	**Lat (^{0} N)**	**Long (^{0} E)**	**Source**	**ERF**	**Zone**
50	Oke Atan Area	07.47385	004.563973	Well	MARKET	2

51	Lagere/ Eleyele1	07.489955	004.545882	Well	WDS	7
52	Lagere/Eleyele2	07.489463	004.545053	Well	WDS	7
53	Lagere/Eleyele3	07.491207	004.544473	Well	WDS	7
54	Lagere/Eleyele4	07.489955	004.545882	Well	WDS	7
55	Lafogido Cmpd	07.479727	004.560868	Well	MARKET	2
56	Igbo-Itapa Cmpd	07.479393	004.562973	Well	MARKET	2
57	Ajamopo Cmpd	07.47947	004.563787	Well	MARKET	2
58	Ayegbaju Cmpd	07.482873	004.565215	Well	MARKET	2
59	Ilelami Cmpd	07.479442	004.56591	Well	MARKET	2

WDS = Waste Dump Site

Ctrl = Control

Abt = Abattoir

Mkt = Market

APPENDIX V: Result for the Locations with 300 meters Spatial Distance to Cholera Incidences and the Environmental Risk Factors

S/n	Co-ordinates		Location	ERFs
1	07.483205	004.56623	Ijio	Waste Dump Site
2	07.491007	004.554393	Sabo1	Waste Dump Site
3	07.490955	004.554085	Sabo2	Waste Dump Site
4	07.491267	004.554698	Sabo3	Waste Dump Site
5	07.482538	004.550602	Ojoyin 1	Waste Dump Site
6	07.48221	004.551472	Ojoyin2	Waste Dump Site
7	07.482662	004.551487	Ojoyin3	Waste Dump Site
8	07.483213	004.56518	Ayegbaju	Waste Dump Site
9	07.82292	004.565605	Ayegbaju 2	Waste Dump Site
10	07.480697	004.56442	Ilode	Waste Dump Site
11	07.478935	004.565658	Ajamopo	Waste Dump Site
12	07.479237	004.566165	Ilelami compound	Waste Dump Site

13	07.47934	004.564933	Ilelami/ Oke Atan	Waste Dump Site
14	07.47755	004.562752	Ayetoro/ Iloro	Waste Dump Site
15	07.479063	004.561065	Ajamopo 2	Waste Dump Site
16	07.493383	004.570993	Esinmirin	Waste Dump Site
17	07.476777	004.561993	Otutu WDS	Waste Dump Site

S/n	Co-ordinates		Location	ERFs
18	07.469813	004.572867	Odi-Olowo	Waste Dump Site
19	07.491077	004.553323	Sabo	Market
20	07.488942	004.554903	Oduduwa Street	Market
21	07.483472	004.563795	Oja Ife	Market
22	07.486062	004.554108	Oja tuntun	Market
23	07.480192	004.556423	Itakogun	Market
24	07.490722	004.554933	Iso obi/Sabo	Market
25	07.489353	004.554967	Oduduwa street	Market

26	07.491077	004.553323	Sabo	Abattoir
27	07.488942	004.554903	Oduduwa Street	Abattoir

APPENDIX VI: **Quality Assurance and Quality Control Measures**

The materials used in the identification of the water samples included the following:

1. Glassware: conical flask, beakers, McCartney bottles, bijo bottles, test tubes
2. Media: Lactose broth, Nutrient agar and broth, peptone water, Sulphide-Indole-Motility (SIM), Koser's citrate agar, Triple Sugar Iron (TSI) agar, ThioSulphate Citrate Bile Salt Sucrose Agar (T C B S), MaConkey agar and broth, Blood agar.

3. Equipment and Instrument: Autoclave, sterilizer, hot air oven, Petri-dish sampling bottles, distiller, boiler, weighing scale, inoculating loops, wires and spindles, Bunsen burner.

Laboratory Precautionary Measures

The following precautions were taken in order to ensure accurate results:

- All sampling bottles and reagent bottles were carefully labeled on the field with a permanent marker to prevent mix up in the laboratory. The water samples collected in sterile bottles were preserved in a cooler and analyzed within 24 hours of sampling as defined by Golterman *et al.,* (1978) and WHO (1997).

- Sterilization Techniques

  All the glass wares were washed with detergent and water, rinsed thoroughly and dried at room temperature. The glass wares containing media were sterilized by auto-claving at 121^0C, 15Ibs ($1kg/cm^2$) pressure for 15 minutes. The inoculating needles and loops were sterilized by flaming in gas, till red heat was obtained and then allowed to cool around flame before use.

- Media Preparation

  The Constituents/ingredients of each medium used for the study were accurately weighed out as given by the manufacturers and dissolved in appropriate amount of water and heated or boiled and then dispensed into test tubes, McCartney bottles and bijou bottles. They were covered properly with the covers or cotton wool and autoclaved at 121^oC for 15 minutes. After autoclaving, some agar media were poured into sterile Petri-disc, some were made into slants in test-tubes.

APPENDIX VII: MPN values of dilutions of 10, 1 and 0.1ml

No. of tubes giving a positive reaction			MPN (per 100ml)	95% confidence limits	
5 of 10ml	**5 of 1ml**	**5 of 0.1ml**		**Lower**	**Upper**
0	0	0	<2	<1	7
0	1	0	2	<1	7

0	2	0	4	<1	11
1	0	0	2	<1	7
1	0	1	4	<1	11
1	1	0	4	<1	11
1	1	1	6	<1	15
2	0	0	5	<1	13
2	0	1	7	1	17
2	1	0	7	1	17
2	1	1	9	2	21
2	2	0	9	2	21
2	3	0	12	3	28
3	0	0	8	1	19
3	0	1	11	2	25
3	1	0	11	2	25
3	1	1	14	4	34
3	2	0	14	4	34
3	2	1	17	5	46
3	3	0	17	5	46
4	0	0	13	3	31
4	0	1	17	5	46
4	1	0	17	5	46
4	1	1	21	7	63
4	1	2	26	9	78
4	2	0	22	7	67
4	2	1	26	9	78

4	3	0	27	9	80
4	3	1	33	11	93
4	4	0	34	12	93
5	0	0	23	7	70
5	0	1	31	11	89
5	0	2	43	15	110
5	1	0	33	11	93

No. of tubes giving a positive reaction			**MPN (per 100ml)**	**95% confidence limits**	
5 of 10ml	**5 of 1ml**	**5 of 0.1ml**		**Lower**	**Upper**
5	1	1	46	16	120
5	1	2	63	21	150
5	2	0	49	17	130
5	2	1	70	23	170
5	2	2	94	28	220
5	3	0	79	25	190
5	3	1	110	31	250

5	3	2	140	37	340
5	3	3	180	44	500
5	4	0	130	35	300
5	4	1	170	43	490
5	4	2	220	57	700
5	4	3	280	90	850
5	4	4	350	120	1000
5	5	0	240	68	750
5	5	1	350	120	1000
5	5	2	540	180	1400
5	5	3	920	300	3200
5	5	4	1600	640	5800
5	5	5	1800	—	—

WHO, 1997

APPENDIX VIII: Coordinate of Sampling Points with the Total Bacteria Count (cfu/ml) and Coliform Bacterial Count (MPN/100ml).

S/n	Locations	Total Bacterial Count cfu/ml	Coliform Bacteria Count MPN/100ml
1	A.P Abattoir	$1.5x10^5$	4
2	Oke-Ola Abattoir	$0.9 x10^6$	11
3	Ola Shehu Abattoir	$1.5 x10^6$	8
4	Ope Oluwa Abattoir	$2.5 x10^6$	4
5	Olanrewaju Dump site	$10.1 x10^7$	1801
6	Ola Jesu Oke Otubu	$0.9 x10^6$	27
7	Al-Wud Olorunsogo	$1.6 x10^6$	2
8	Ondo Road Abattoir	$1.0 x10^6$	1
9	Old Nepa Abattoir	$1.0 x10^7$	6
10	Famia Road Dump Site	$5.6 x10^7$	12

12	Iyana Oduduwa Abb	1.0×10^6	6
13	Oja Ife Waste Dump	0.7×10^5	2
14	Oja Ife Market	0.5×10^5	2
15	Adura Abb Olorunsogo	1.5×10^6	34
16	Olorunsogo	0.3×10^5	3
17	Olorunsogo	0.4×10^5	2

S/n	Locations	Total Bacterial Count (cfu/ml)	Coliform Bacteria Count (MPN/100ml)
18	Olorunsogo	0.4×10^5	12
19	Olorunsogo Market	0.6×10^6	2
20	Better Life Abattoir	1.9×10^6	6
21	Better Life Market	1.1×10^5	6
22	Ola-Olu Well	2.0×10^7	1801
23	Ola-Olu Abattoir	3.3×10^7	17

24	Sabo Waste Dump site	3.4×10^7		21	
25	Sabo Wds2	2.3×10^7		33	
26	Sabo Abattoir	19.5×10^7			1801
27	Oduduwa Strt Abat	6.0×10^7	1801		
28	Oduduwa Strt RDS/Slum	2.4×10^7		540	
29	Akaui Strrt Rds	2.4×10^7		27	
30	Oja Titun Market	3.1×10^7		3	
31	Iyana Oja WDS	10.1×10^7			50
32	Ojoyin Waste Dump site	1.6×10^6		17	

S/n	**Locations**	**Total Bacteria Count (cfu/ml)**	**Coliform Bacteria Count (MPN/100ml)**

33	Orita Fogo WDS	1.7×10^6	9	
34	Itakogun Market	0.2×10^6		4
35	Ita Agbon Abat	3.0×10^6		9
36	Ojoyin WDS	0.6×10^7	17	
37	Isale-Agbara Abat	3.0×10^7	17	
38	Monyashiu Abt Isale Abara	1.5×10^7	12	
39	Olonade Street	3.4×10^7	24	
40	Isale Agbara Street	1.7×10^7	6	
41	Apata Street	1.1×10^7	4	
42	Ibadan Exp Rd	0.7×10^6		8
43	Aladanla Abattoir	0.6×10^6	12	
44	Iloro Market	0.4×10^6	9	
45	Bosa Market	0.4×10^6	6	
46	Mayfair Market	0.3×10^5	2	
47	Oke-Atan Market	0.6×10^7	8	

S/n	Locations	Total Bacterial Count (cfu/ml)	Coliform Bacteria Count (MPN/100ml)
48	Kosere Abattoir	0.5×10^7	12
49	Iraye Dumpsite	0.3×10^7	2
50	Oke Atan Area	0.8×10^7	4
51	Lagere/ Eleyele1	0.4×10^6	1
52	Lagere/Eleyele2	0.2×10^5	1
53	Lagere/Eleyele3	0.2×10^5	1
54	Lagere/Eleyele4	0.2×10^5	2
55	Lafogido Cmpd	2.0×10^5	1801
56	Igbo-Itapa Cmpd	1.1×10^5	24
57	Ajamopo Cmpd	1.2×10^5	6
58	Ayegbaju Cmpd	3.2×10^7	1801
59	Ilelami Cmpd	2.0×10^7	540

APPENDIX IX: Line List of Gastro-Enteritis Cases Reported at Ife Central LGA of Osun State (August, 2010)

IDNO	STATE	LGA	WARD	SETTLEMENT
001	Osun	Ife Central	Ilare 10	Sabo
002	Osun	Ife Central	Ilare 10	Sabo
003	Osun	Ife Central	Ilare 10	Sabo
004	Osun	Ife Central	Ilare10	Sabo
005	Osun	Ife Central	Ilare10	Sabo

006	Osun	Ife Central	Ilare 10 Sabo
007	Osun	Ife Central	Ilare 10 Sabo
008	Osun	Ife Central	Ilare 10 Sabo
009	Osun	Ife Central	Ilare 10 Sabo
010	Osun	Ife Central	Ilare 10 Sabo
011	Osun	Ife Central	Ilare 10 Sabo
012	Osun	Ife Central	Ilare 10 Sabo
013	Osun	Ife Central	Ilare 10 Sabo
014	Osun	Ife Central	Ilare 10 Sabo
015	Osun	Ife Central	Ilare 10 Sabo

IDNO	STATE	LGA	WARD	SETTLEMENT
016	Osun	Ife Central	Ilare	10 Sabo

017	Osun	Ife Central	Ilare 10 Sabo
018	Osun	Ife Central	Ilare 10 Sabo
019	Osun	Ife Central	Ilare 10 13, Ogbingbin Strt
020	Osun	Ife Central	Ilare 10 Sabo
021	Osun	Ife Central	Ilare 10 Sabo
022	Osun	Ife Central	Ilare 10 Sabo
023	Osun	Ife Central	Ilare 10 Sabo
024	Osun	Ife Central	Ilare 10 Sabo
025	Osun	Ife Central	Ilare 10 Sabo
O26	Osun	Ife Central	Ilare 10 Sabo
027	Osun	Ife Central	Ilare 10 Sabo
028	Osun	Ife Central	Ilare 10 Sabo
029	Osun	Ife Central	Ilare 10 Sabo
030	Osun	Ife Central	Ilare 10 Sabo
031	Osun	Ife Central	Ilare 10 Seminary Opa
032	Osun	Ife Central	Ilare III Ilare

IDNO	STATE	LGA	WARD	SETTLEMENT
033	Osun	Ife Central	Ilare 10 Sabo	
034	Osun	Ife Central	Iremo III	Olubuse
035	Osun	Ife Central	Iremo III	Olubuse
036	Osun	Ife Central	Ilare II	Ajegunle
037	Osun	Ife Central	Moore/Ojaja	Agric Area
038	Osun	Ife Central	Ilare I	Mount Zion
039	Osun	Ife Central	Ilare I	Moore
040	Osun	Ife Central	Ilare 10 Sabo	
041	Osun	Ife Central	Ilare 10 Sabo	
042	Osun	Ife Central	Iremo II	Eleyele
043	Osun	Ife Central	Iremo II	Iredunmi
044	Osun	Ife Central	Ilare 10 Sabo	

APPENDIX X: Recorded Cases of Persons Diagnosed of Severe Gastro-Enteritis at Oke- Ogbo LGA, Ile-Ife, Osun State (17th of October 2011)

IDNO	STATE	LGA	WARD	SETTLEMENT
23508	Osun	Ife east	Ilode I	14, Igbo itapa
23527	Osun	Ife east	Okerewe II	29, Lafojido
23517	Osun	Ife east	Ilode I	Bk 17, Ajamopo
23537	Osun	Ife east	Ilode I	Bk 17, Ajamopo
23540	Osun	Ife east	Ilode I	26, Ayegbaju strt

11486	Osun	Ife east	Okerewe I	48, Odi-olowo Strt
114905	Osun	Ife east	Moore	42, Mokuro road
114906	Osun	Ife east	Ilode I	50, Ilelami Compound

APPENDIX XI: Located Residence of Cases at Ife Central (August, 2010)

S/n	Locations	Long (^{0} E)	Lat (^{0} N)
1.	Sabo	004.554862	07.491038

2.	13, Ogbingbin	004.552293	07.484630
3.	Seminary opa	004.570465	07.521842
4.	Ilare	004.556458	07.490795
5.	Olubuse	004.558130	07.497465
6.	Ajegunle	004.563083	07.497032
7.	Agric Area	004.573732	07.533373
8.	Mount Zion	004.589283	07.498228
9.	Moore	004.566738	07.490868
10.	Eleyele	004.545620	07.490347
11	Iredunmi	004.558257	07.482020

APPENDIX XI: Located Residence of Cholera Cases at Ife East Local Government Areas (October, 2011)

S/n	Ife East LGA	Long (^{0}E)	Lat (^{0}N)
1.	14, Igbo-Itapa	004.562142	07.480715
2.	29, Lafogido junction	004.561255	07.479310
3.	Bk 17, Ajamopo	004.563903	07.477990
4.	26, Ayegbaju Street	004.565123	07.482660
5.	48, Odi-olowo Street	004.572768	07.468603
6.	42, Mokuro Road	004.569990	07.493120
7.	50, Ilelami compound	004.565858	07.479435

APPENDIX XII: Result of Biochemical Tests

OXIDASE	CITRATE	UREASE	INDOLE	MOTILITY	H_2S	GAS	GLU	LAC	SUC	ORGANISM INDICATED
-	+	+	-	-	-	+	+	+	+	*Citrobacter koseri*
-	+	+	-	+	-	+	+	+	+	*Enterobacter aerogenes*
-	-	-	+	+	-	+	+	+	+	*Escherichia coli*
-	+	+	-	+	+	+	+	-	+	*Proteus mirabilis*
-	+	+	-	-	-	+	+	+	+	*Klebsiella aerogenes*
-	+	-	-	+	+	+	+	+	+	*Citrobacter freundii*
-	+	+	-	-	-	+	+	+	+	*Klebsiella pneumoniae*
-	-	-	-	+	+	-	+	-	-	*Salmonella typhi*
-	-	-	-	-	-	-	-	-	-	*Shigella dysenteriae*
+	+	-	+	+	-	-	+	-	+	*Vibrio cholerae*

APPENDIX XIII: A Structure Questionnaire Used at Sampling Locations

Institute of Ecology and Environmental Studies

Obafemi Awolowo University

Ile-Ife, Osun State, Nigeria

A Structured Interview Schedule at Each Location

Part 1: Socio-demographic Questions

Gender **(a.) Male (b.) Female**

Age……

Marital Status **(a.) Single (b.) Married (c.) Divorced (d.) Widowed**

Location……

Educational Level **(a.) None (b.) Primary (c.) Secondary (d.) Tertiary**

Part 2: Environmental Hygiene Practices of Respondents at Each Location

1. Where do you dispose your waste?

   (**a.) River (b.) Stream (c.) Bushes (d.)Drainage (e.) Backyard**

2. Does Government provide refuse vans for waste collection?

   (**a.) yes (b.) no**

3. What source of water do you use for your daily activities?

   (a.) well (b.) River (c.)Stream (d.) Tap (e.) Bore hole

4. Where do you defecate?

   (a.) pit latrine (b.) River (c.)Stream (d.)Water closet (e.) Bushes

5. Do you always treat your domestic wastes before disposal?

   (a.) Yes (b.) No

6. Have you experienced any form of flooding in this area before?

   (a.) yes (b.) no

7. How covered is your well?

   (a.) fully covered (b.) Partially covered (c.) No cover

8. What type of wall protection is inside your well?

   (a.) Rings (b.) Plaster (c.) Nothing

9. Have you ever treated your source of water?

   (**a.) yes (b.) no**

10. What type of treatment do you use?

    (a.) **chlorination** (b) **salting** (c) **filtration** (d) **addition of alum**

11. Who is funding the treatment?

    (**a.) State government (b.) Local government (c.) Non-governmental**

    (d.) Church (e.) Individual (e.) others

12. When last did you treat your source of water?

    (a.) this month (b.) Last 6months (c.)Last year (d.) Never

13. Has there been any environmental sanitation education for you in your area?

    (a.) Yes (b.) No

14. Who are the people doing this**?**

    (a.**) state government (b.) Local government (c.)Non-governmental**

    (d.) Church (e.) Others please specify…….

15. Do you observe any routine environmental sanitation?

(a.) Yes (b.) No

16. What type of environmental sanitation do you observe in your environment?

(a.) Government imposed (b.) Individual

(c.) landlord association Environmental sanitation

17. Where do you report any case of disease outbreak?

(a.) Hospital (b.) Health center (c.) Church (d.)Mosque (e.)Herbalist

(f.) Nowhere

18. Do you have any Health care facility close-by?

(a.) yes (b.) no

19. Which of these diseases have you had in the last five years?

i. Cholera (Yes) (No)

ii. Diarrhea (Yes) (No)

iii. Typhoid fever (Yes) (No)

iv. Dysentery (Yes) (No)

20. How long has the environmental factor been located? ----------